BULLETIN No. 101.

U. S. DEPARTMENT OF AGRICULTURE.
OFFICE OF EXPERIMENT STATIONS.
A. C. TRUE, Director.

STUDIES

ON

BREAD AND BREAD MAKING

AT

THE UNIVERSITY OF MINNESOTA

IN

1899 and 1900.

BY

HARRY SNYDER, B. S.,
Professor of Chemistry, College of Agriculture, University of Minnesota, and Chemist, Agricultural Experiment Station.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1901.

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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Office of Experiment Stations,
Washington, D. C., June 28, 1901.

Sir: I have the honor to transmit herewith a report of investigations on bread and bread making at the University of Minnesota in 1899 and 1900 by Harry Snyder, professor of chemistry in the Agricultural College of the University of Minnesota and chemist of the agricultural experiment station. The investigations were carried on under the supervision of Prof. W. O. Atwater, special agent in charge of nutrition investigations, and Prof. Charles D. Woods, in accordance with instructions given by the Director of this Office. Many of the baking tests were made in the testing room of the Washburn-Crosby Company of Minneapolis, Minn., who offered the use of their well equipped experimental bakery for the purpose.

In connection with the nutrition investigations of the office numerous studies of bread and breadmaking have been made at different institutions, Professor Woods having had immediate charge of this line of work. In such investigations the special objects have been the determination of the comparative nutritive value of bread made from different grades of flour, the effect of different methods of making and baking bread upon its composition and digestibility, and related problems. A special point in connection with Professor Snyder's report is that the different samples of flour used were all ground from the same lot of wheat. His investigations form an unusually satisfactory basis for judging the comparative nutritive value of so-called "graham" flour, which contains the whole of the wheat grain and is really an unbolted wheat meal; so-called "whole-wheat" or "entire-wheat" flour, obtained by removing part of the bran and grinding the rest of the kernel; and ordinary patent flour. The report is submitted with the recommendation that it be published as Bulletin No. 101 of this Office.

Respectfully,

A. C. True,
Director.

Hon. James Wilson,
Secretary of Agriculture.

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STUDIES ON BREAD AND BREAD MAKING.

INTRODUCTION.

Investigations on bread and bread making, and on flour and its relation to bread, which were carried on at the University of Minnesota in 1897 and 1898 have already been published.[1] These investigations have been continued, and the purpose of the present bulletin is to report the results of those completed during 1899 and 1900. The special subjects considered in this bulletin are (1) the comparative nutritive value—including both composition and digestibility—of graham flour, entire-wheat flour, and standard patent roller-process flour; (2) the comparative digestibility of bread and of oatmeal in experiments with a ration consisting of (*a*) a large, (*b*) a medium, and (*c*) a small amount of bread and milk, and (*d*) a large and (*e*) a small amount of oatmeal and milk; (3) the digestibility of bread made from flour in which the proportion of starch is increased; (4) the quality of the bread as affected by (*a*) increasing or diminishing the proportion of starch, (*b*) raising or lowering the temperature of the flour, (*c*) prolonged heating of the flours, and (*d*) blending of different types of flour.

COMPARISON OF THE NUTRITIVE VALUES OF GRAHAM, ENTIRE-WHEAT, AND STANDARD PATENT ROLLER-PROCESS FLOURS.

The value of any material as a food depends not only upon the amounts of nutrients which the material contains, as indicated by its composition, but also upon the proportions of those nutrients which can be digested and made available to the body. In order to determine and compare the actual nutritive values of graham, entire-wheat, and standard patent roller-process flours, not only were complete analyses of these materials made and heats of combustion determined, but a series of digestion experiments with men was conducted, in which a considerable portion of the diet consisted of bread made of the different flours. It is to be particularly observed that the "graham" flour is unbolted wheat meal, while the so-called "whole-wheat," or entire-wheat flour, contains all of the kernel except a portion of the bran. The "patent" and "clear grade" flours contain practically none of the bran or episperm and very little of the germ or embryo of the wheat kernel. The methods and results of these investigations are reported in the following pages.

[1] U. S. Dept. Agr., Office of Experiment Stations Bul. 67.

Numerous analyses have been made of different kinds of flour, and the digestibility of bread has been studied by several investigators. The results obtained are valuable, but are not sufficient for an accurate comparison of the nutritive values of different grades of flour in general, for the reason that there was probably a considerable variation in the composition of the wheat from which the different flours were milled. The protein in samples of flours purchased in the open market has been found to range from 7 to 14 per cent. In some cases the proportion of protein is higher and in other cases lower in standard patent than in entire-wheat or graham flours. That these differences in the protein content of different samples of flour are due to variations in the composition of the wheat from which the various flours were ground is indicated by the figures for analyses of wheat given in the report of Jenkins and Winton on the composition of American feeding stuffs.[1] The average protein content of 310 samples of wheat is there given as 11.9 per cent, the range being from 8.1 to 16.6 per cent. While such extreme variations are found occasionally, a range from 11 to 15 per cent is not exceptional. If wheat with 15 per cent of protein were made into ordinary white flour and wheat with 11 per cent of protein were made into entire-wheat or graham flour, the former would contain appreciably more protein than the latter, but if the wheat with 15 per cent of protein were made into entire-wheat or graham flour and that with 11 per cent into ordinary white flour the result would be the reverse.

It is evident from such facts as these that a fair comparison of the nutritive values of the different kinds of flour—graham, entire-wheat, and standard patent—can be made only when the three kinds of flour have been milled from the same lot of wheat. This was done in the investigations here reported, a hard, Scotch Fife spring wheat being used. The importance of the subject, it is believed, has justified this systematic inquiry.

The careful milling of the wheat so as to secure representative samples of the three kinds of flour from the same lot was of considerable importance. This work was done under the supervision of Mr. C. E. Foster, of Minneapolis, Minn., in one of the large mills of that city. Samples of patent flour and the accompanying milling products were obtained, and from the same lot of wheat graham and entire-wheat flours were ground.

A check upon the milling was made in the following manner: The composition[2] of the wheat before milling was determined by analyzing a sample ground in the laboratory, and from this analysis the total amounts of nitrogen and ash in 1,000 pounds of wheat were calculated. After the wheat was milled the proportions of the 1,000 pounds recovered in the different milling products were determined. These

[1] U. S. Dept. Agr., Office of Experiment Stations Bul. 11.

[2] See sample No. 51, Table 3.

are given in the first column of figures in Table 1. Analyses of the milling products were then made, and from the composition (see Table 3) of each material and its percentage of the original wheat the total amounts of nitrogen and ash in each of the milling products were calculated. Dividing these by the amounts of nitrogen and ash in the original wheat gave the proportions recovered in the different milling products. These results are given in the last two columns in Table 1. By this method any error in milling, sampling, or analyzing would be discovered, because practically all of the nitrogen and ash of the original wheat should be recovered in the flour and other milling products.

TABLE 1.—*Proportions of total weight of wheat and of its nitrogen and ash content recovered in the different milling products.*

Milling products.	Proportion of original wheat.	Proportion of total nitrogen and ash in original wheat.	
		Nitrogen.	Ash.
	Per cent.	*Per cent.*	*Per cent.*
Standard patent flour	72.6	69.50	20.23
Second clear (low-grade flour	.5	.60	.49
Red dog flour	1.9	2.85	3.67
Shorts	11.6	13.70	29.38
Bran	13.4	14.50	45.12
Total	100.0	101.15	98.89

From the figures in this table it will be observed that 101.15 per cent of the total nitrogen and 98.89 per cent of the total ash of the wheat were recovered in the milling products. The variations from 100 per cent are small, and are probably due to removal of dust during milling and to slight variations in manipulation in sampling and analyzing the several milling products.

Care was taken to secure for these investigations uniform and representative samples of the different milling products. Two separate lots of samples were drawn as follows: One hundred pounds each of standard patent and entire-wheat flours, 50 pounds of graham flour, 10 pounds each of the first and second patent grades of flour, first and second clear grades of flour, "red dog" flour, shorts, and bran. By means of sampling tubes smaller amounts of each lot of flour and other milling products were also obtained and sealed in bottles for analytical purposes. A description of the different samples of flour and milling products and of the wheat from which they were ground follows:

DESCRIPTION OF SAMPLES.

No. 41. First patent flour; produced by the roller process of milling. This is the highest grade of patent flour manufactured. The gluten from this flour has a greater power of expansion than that from any other grade, and the flour also absorbs the most water and produces the whitest and largest sized loaf of bread.

No. 42. Second patent flour, sometimes called standard Minneapolis patent flour. It is similar to first patent flour, but the bread produced is a shade darker in color, and the gluten does not possess quite so high a power of expansion.

No. 43. Standard patent flour is made up of the sum of the first and second patent grades and the first clear or bakers' grade of flour, and is the ordinary bread flour most frequently found on the market. It is used in this investigation as the standard for comparison with the entire-wheat and graham flours. About 72.6 per cent of the screened wheat is recovered as standard patent flour.

No. 44. First clear grade flour. After the first and second grades of patent flour are removed, about 11.8 to 12 per cent of the first clear grade flour is obtained, which contains slightly more protein than either the first or second patent flour. The protein, however, does not contain gliadin and glutenin in the right proportions to produce so good a quality of bread as the patent grade flours.

No. 45. Second clear or low grade flour. After the standard patent flour has been removed there is obtained about 0.5 per cent of flour called second clear or low grade, which contains a high percentage of protein. The gluten, however, is of poor quality for bread-making purposes.

No. 46. "Red dog" flour. This is the lowest grade of flour produced. It is dark in color and has but little power of expansion. It is secured largely from the germ or embryo and adjacent portions of the wheat, and contains a relatively high percentage of protein. "Red dog" flour produces a small and dark-colored loaf of bread as compared with flour of better quality.

No. 47. Middlings or shorts. About 11.6 per cent of the cleaned wheat is recovered in middlings, which consists of the fine bran that has been more completely pulverized. When this product contains a large part of the germ it is much richer in protein than ordinary shorts and is called shorts middlings. The term middlings, as used in this sense, should not be confused with the same term applied to the material obtained when wheat is milled by the old process. The middlings of the old process are now reduced and recovered in the various grades of patent flours.

No. 48. Bran. This is the episperm or outer covering of the wheat kernel.

No. 49. Entire-wheat flour. This is the product obtained by removing a portion of the bran and then grinding the remainder of the wheat kernel. The flour is of a coarser texture than the patent and clear grades. Entire-wheat flour is sometimes called "purified graham" or "natural" flour.

No. 50. Graham flour. This is the entire-wheat kernel (bran and all) ground into meal. The presence of the bran prevents the fine grinding of the material, and particles of the bran are apparent when the flour is examined. Graham flour is practically wheat meal. No sieves or bolting cloths are employed in its manufacture, and many coarse particles of unpulverized material are present in the product.

No. 51. Cleaned wheat, scoured and polished for milling. This is a hard, Scotch Fife spring wheat, plump, and of good quality, weighing 60 pounds per bushel. The sample analyzed was ground in the laboratory in a Maercker mill. All of the grades of flour and the various products given in the list of samples were obtained from this wheat.

No. 52. Gluten flour. This is a flour containing as high a percentage of protein as it is possible to secure by the ordinary roller-process milling. It is not composed entirely of gluten, but simply contains a high percentage of this material. No flour can be composed entirely of gluten.

By mixing various amounts of the different standard grades of flour described above, large numbers of flours with different trade names are obtained. Many of the brands of flour sold in the market are produced by blending different amounts of the patent and clear grades of flour.

COMPOSITION OF SAMPLES.

Complete proximate analyses of all the flours and other milling products were made mainly according to the methods recommended by the Association of Official Agricultural Chemists.[1] The results are given in Table 2. The acidity of the samples was determined, as was also the heat of combustion. The calculated heats of combustion are also given for purposes of comparison, using the factors given on page 22. The value for protein given in this table was calculated as nitrogen multiplied by the factor 5.7 instead of by the usual factor 6.25. While by the use of this factor the value for the protein is lower, it undoubtedly represents more nearly the actual amount than the value obtained by the use of the factor 6.25. However, for the sake of comparison with investigations previously reported, protein has been computed by use of the factor 6.25 in the experiments reported beyond.

All of the materials in which the determination of the ether extract was made were first dried in a water oven at 70° C. for about two hours.

TABLE 2.—*Composition, acidity, and heats of combustion of flours and other milling products of wheat.*

Sample No.	Milling product.	Water.	Protein (N×5.7).	Fat.	Carbohydrates.	Ash.	Phosphoric acid.	Acidity calculated as lactic acid.	Heat of combustion per gram.	
									Calculated.	Determined.
		P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*Calories.*	*Calories.*
41	First patent flour	10.55	11.08	1.15	76.85	0.37	0.15	0.08	3.989	4.032
42	Second patent flour	10.49	11.14	1.20	76.75	.42	.17	.08	3.992	4.006
43	Straight or standard patent flour	10.54	11.99	1.61	75.36	.50	.20	.09	4.022	4.050
44	First clear grade flour	10.13	13.74	2.20	73.13	.80	.34	.12	4.087	4.097
45	Second clear grade flour	10.08	15.03	3.77	69.37	1.75	.56	.27	4.153	4.267
46	"Red dog" flour	9.17	18.98	7.00	61.37	3.48	....	.59	4.349	4.485
47	Shorts	8.73	14.87	6.37	65.47	4.56	....	.14	4.219	4.41[illegible]
48	Bran	9.99	14.02	4.39	65.54	6.06	2.20	.23	3.988	4.[illegible]
49	Entire-wheat flour	10.81	12.26	2.24	73.67	1.02	.54	.32	4.[illegible]	4.[illegible]32
50	Graham flour	8.61	12.65	2.44	74.58	1.72	.71	.18	4.123	[illegible].148
51	Wheat ground in laboratory	8.50	12.65	2.36	74.69	1.80	.75	.18	4.114	4.140
52	Gluten flour	8.57	16.36	3.15	70.63	1.29	....	.14	....	....

From the figures in the table it will be seen that from the first patent to the "red dog" grade of flour there was a gradual decrease in the water content, and from the first patent flour to the bran there was a noticeable increase in the ash content. The ash in the wheat kernel varies so little in different samples of the same wheat, and the ash content varies so regularly in the different grades of milling products, that it is possible to determine the grade of flour by determining the amount of ash which it contains. In fact, the mixing of

[1] U. S. Dept. Agr., Division of Chemistry Bul. 46, revised.

grades can be detected more readily by determining the percentage of ash than by the study of any other constituent.[1]

There was but little difference in chemical composition between the first and second grades of patent flour, the second patent containing slightly more protein and fat and less carbohydrates than the first. The standard patent flour contained nearly 12 per cent protein, while the wheat from which it was made contained about 12.65 per cent. As a general rule the proportion of protein in standard patent flour is only from 0.6 to 0.7 per cent less than that in the wheat from which it was milled. The second clear and "red dog" flour samples are characterized by a high percentage of protein, fat, and ash. Judged by their proximate composition only, these flours might appear to have a higher nutritive value than the patent flours or the first clear grade; but when judged by the character of the bread made from them they must be assigned a much lower value.

The wheat (sample No. 51) ground in the small mill at the chemical laboratory had practically the same composition as the graham flour ground in the larger mill by the regular commercial method.

ACIDITY OF SAMPLES.

The acidity of the samples was ascertained by titrating a measured quantity of the aqueous extract from a weighed amount of each of the different milling products with a standard alkali solution, using phenolphthalein as an indicator. The results, calculated as lactic acid, are shown in Table 2. While the method employed for the determination of the acidity does not give the total amounts of acid present, it does give relative amounts which serve for comparison. The "red dog" flour, for example, contains seven times as much acid as the first or second patent flour. The percentage of acid gradually increases as the grade of flour decreases, the lowest grade containing most acid. The determination of acidity has been found to possess a unique value in testing wheat for commercial purposes. Wheats of high acidity, while apparently sound, invariably produce flours which are of poor keeping qualities, and which make inferior grades of bread. The development of acid in bread making and the nature of the acid were discussed in a former report.[2]

HEAT OF COMBUSTION OF SAMPLES.

The heats of combustion of the various samples of flour and other milling products, given in Table 2, were determined by use of the bomb calorimeter (fig. 1). The apparatus, which is a modification of that of Berthelot, devised especially for use in such investigations as

[1] The use of the ash content as a means of classifying flours was recently discussed by Fabris and Severini. Ann. Gabelle Roma, 3 (1898), p. 27; abs. in Bul. Soc. Chim. Paris, 20 (1898), p. 109.

[2] U. S. Dept. Agr., Office of Experiment Stations Bul. 67, p. 19.

these, and the method of manipulation have been described in detail in a former report of this Office,[1] and in publications of the Connecticut (Storrs) Experiment Station.[2]

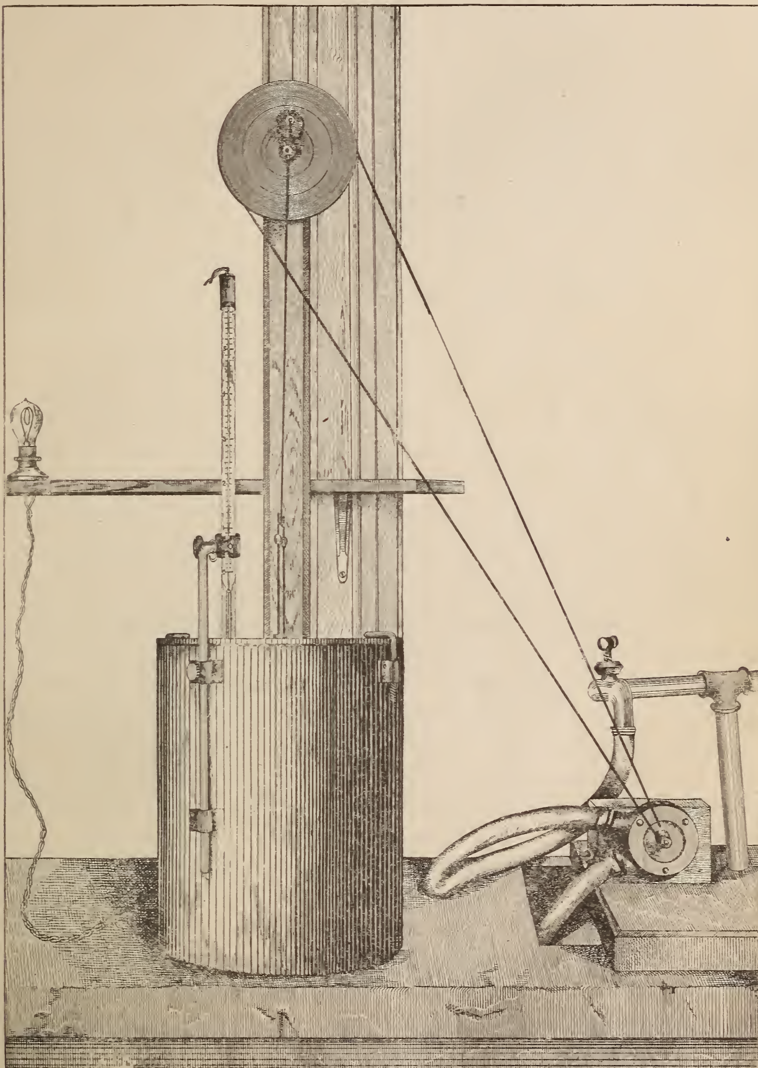

FIG. 1.—Bomb calorimeter.

The bomb is made of fine steel and is lined with platinum. It consists of a cylinder to contain the substance to be burned and the oxygen

[1] U. S. Dept. Agr., Office of Experiment Stations Bul. 21.
[2] Connecticut Storrs Sta. Rpts. 1894 and 1897.

for combustion, a cover to close the cylinder, and a collar to hold the cover tightly upon the cylinder. The material to be burned is compressed into a pellet in a press and is then placed in a small platinum capsule which is suspended by platinum wires from the cover of the bomb. A coil of fine iron wire, for igniting the substance electrically, is stretched between the two platinum wires which support the capsule and is made to rest upon the pellet within the capsule. The cover is then screwed tightly upon the cylinder of the bomb, and the oxygen is introduced through a valve in the cover until the pressure in the bomb is 20 atmospheres. The valve is then tightly closed and the bomb is placed in a Britannia metal receptacle containing a definite quantity of water the temperature of which is known. A metal stirrer, operated in this laboratory by a water motor, keeps the water in the receptacle in motion during the whole operation, and thus equalizes the temperature. When the bomb is immersed, a current of electricity is passed through the coil of wire resting upon the substance in the capsule, causing the wire to become incandescent and to ignite the substance. Combustion takes place immediately, and the heat passes through the metal of the bomb and is absorbed by the water surrounding it. A calibrated Fuess thermometer is immersed in the water, and measures the rise in temperature of this known amount of water, from which the heat of combustion of the material is calculated, due allowance being made for the hydrothermal equivalent of the bomb and apparatus containing it (i. e., for the amount of heat absorbed by these), for the heat introduced by the current of electricity in igniting the substance, the heat developed by oxidation of the metal fuse and small amount of nitrogen, etc. The hydrothermal equivalent of the bomb used in these investigations was determined by the combustion of samples of sucrose and of other substances of known purity.

The heats of combustion of the various samples of flour and other milling products were calculated by the use of the following factors: Protein, 5.9; fat, 9.3; and carbohydrates, 4.2 calories per gram. The heats of combustion as calculated, in comparison with those determined with the calorimeter, are given in Table 2. The factors given above were used because they represent in round numbers the results of the actual combustion of samples of protein, fat, and starch, prepared in the following manner from flour numbered 43 in the preceding description of samples:

Starch.—A stiff dough was made from 50 grams of flour, and the starch was separated from the gluten by washing. The starch in the wash water was collected in a beaker and allowed to settle. It was then washed with distilled water by decantation, and finally with dilute alcohol, strong alcohol, and ether, successively. Before combustion the substance was carefully dried. Analysis showed that the

sample contained only a trace of nitrogen and a small amount of ash.

Fat.—Fat (ether extract) was obtained by extraction in a Soxhlet apparatus. Pure anhydrous ether was used for the extraction.

Gliadin and glutenin.—The gluten proteids, gliadin and glutenin, were prepared from the gluten obtained in the separation of starch. The gluten was cut into small pieces and extracted for several days with 70 per cent alcohol. The gliadin obtained from the alcoho extract was redissolved, purified, and dried over sulphuric acid. Bothl gliadin and glutenin hold water very tenaciously and can be dehydrated only with difficulty. The gliadin contained 0.34 per cent ash, and the glutenin 0.44 per cent, which were taken into account in determining the heat of combustion.

From the combustions of the substances described above the following values were obtained:

TABLE 3.—*Heat of combustion of constituents of flour.*

Sample No.	Material.	Number of determinations.	Heat of combustion per gram.
			Calories.
89	Wheat starch	2	4.191
90	Wheat fat	2	9.282
91	Gliadin	3	5.924
92	Glutenin	3	5.879

The gluten of the flour (sample No. 43) used for preparing the above constituents contained 62 per cent gliadin and 38 per cent glutenin. Its heat of combustion, as calculated from the above values for gliadin and glutenin, was therefore 5.906 calories per gram.

By comparing the heats of combustion of the different samples of flour and other milling products of wheat, shown in Table 2, as calculated by the factors given above and as actually determined by the bomb calorimeter, it will be seen that for the flours the values as calculated and as determined agree quite closely, but for the bran, shorts, and other products which contain more cellulose the agreement is not so close.

The water of hydration of wheat proteids.—As previously stated, protein is calculated in these investigations as nitrogen multiplied by the factor 5.7. But this product represents strictly anhydrous proteids, while the proteids present in flour are not in that condition. When dried at 100° C. the gliadin retained 4.22 per cent water, which was expelled between 101° and 102° C.; and the glutenin retained 4.66 per cent water, which was likewise driven off only with difficulty. It is difficult to separate and obtain these proteids in a pure form without chemical changes. From these facts, and from results obtained with the bomb calorimeter, as explained below, it would appear that as ordinarily present in flour the gluten proteids are in part in

hydrated forms. Therefore, as these proteids are alike subject to hydration and other changes, it is an open question whether 5.7 or some other factor is the proper one for calculating the protein content in wheat. When the greatest accuracy of composition is desired, this water of hydration of the proteids should be added to the water determined in the usual way, and should not be credited to the carbohydrates, as it is when the latter are calculated as the difference between 100 per cent and the sum of the percentages of ash, protein, fat, and the water driven off at 100° C. According to the method used for determining the ingredients reported in Table 2, the value for water of hydration is contained in the value for the carbohydrates.

When samples of flour are preserved three to six months, there appears to be a pronounced change in the moisture content. After samples of the flours and milling products used in these investigations had been kept in sealed bottles in a cool place for six months the determined moisture content of all of them averaged about 2.5 per cent less than the figures for water in the fresh samples reported in Table 2. If so great a change in moisture had actually occurred, the calculated and the determined heats of combustion given in Table 2, which are on the basis of the water content of the fresh samples, would differ from the heats of combustion determined for the preserved samples. But the difference between the determinations made on samples that had been kept three months and those made on the fresh samples was no greater than the difference between duplicate determinations made on the same sample. It would seem, therefore, that the apparent loss of water in the sample preserved is simply due to the hydration of the gluten proteids; that is, to the fact that the water is held in such a way that it is not driven off by the ordinary method—i. e., drying at 100° C. The experiments suggest that in the mixing and other stages of bread making the hydration of the gluten proteids is one of many important changes which take place in flour, and that water plays a chemical as well as a physical part in bread making.

DIGESTION EXPERIMENTS WITH BREAD FROM FLOURS OF DIFFERENT GRADES.

Only that portion of the food that is digested is useful to the body for nourishment. For an accurate comparison of the actual nutritive values of graham, entire-wheat, and standard patent flour, it is necessary to determine what proportions of the nutrients in each will be digested. To gain information on this point, a series of nine digestion experiments with three subjects was carried on, in which the diet consisted of milk and bread made from the different grades of flour. At the same time, to determine whether there is any difference in the digestibility of different grades of patent flour, three experiments with

another subject were made with first patent, second patent, and standard patent flours, instead of with graham, entire-wheat, and standard patent. The subjects were young men in good health, designated in these experiments as Nos. 1, 2, 3, and 4. In so far as possible the experiments were alike, except as regards the kind of flour from which the bread eaten was made. The method followed was similar to that explained in detail in a former bulletin of this Office.[1] All the food consumed and feces excreted were weighed and samples were analyzed. The separation of the feces for the experimental period was made by the use of charcoal,[2] which was given to the subjects in capsules with the last meal before and the first meal after each period. The digestibility of the bread and milk diet as a whole was measured by the difference between the total nutrients in the diet and those in the feces. Then, as explained later, by assuming certain factors for the digestibility of the nutrients in the milk, the digestibility of those in the bread alone was estimated.

The first three of the twelve experiments were carried on simultaneously, the three subjects, Nos. 1, 2, and 3, being fed upon bread made from standard patent flour, and in addition sufficient milk to make the diet palatable. A single experiment was then made, the subject, No. 4, consuming bread made from first patent flour, with milk in addition as before. A little later three more experiments were carried on together, with subjects Nos. 1, 2, and 3, the diet in this case consisting of bread made from entire-wheat flour, consumed with milk. Following this was a single experiment with subject No. 4, in which the diet consisted of bread made from second patent flour, and milk. Another single experiment was made with subject No. 4 on a diet of bread made from standard patent flour, and milk; and finally, three more experiments with subjects Nos. 1, 2, and 3, the diet consisting of bread made from graham flour, with milk as before.

Each experiment lasted two days, and was preceded by a preparatory meal similar to that eaten during the experiment proper. In each case the bread eaten consisted only of the moist crumb. It was found necessary to remove the crust, because when the latter was included accurate sampling of the bread was difficult, and the determinations of ether extract were interfered with. During each digestion period one loaf (crumb only) was taken as a sample for analysis, and three separate subsamples were taken for the determination of moisture, which was made in three ways: (1) Drying in a water oven at 100° C.; (2) drying in an air bath at 70° C., and (3) drying over

[1] U. S. Dept. Agr., Office of Experiment Stations Bul. 85.

[2] See description of method in U. S. Dept. Agr., Office of Experiment Stations Bul. 21, p. 58.

sulphuric acid. A comparison of the results obtained by these three methods for the determination of water in several samples of bread is given in Table 4.

Table 4.—*Water content of bread as determined by different methods of drying.*

Sample.	Dried in water oven at 100° C.	Dried in air bath at 70° C.	Dried over sulphuric acid.
	Per cent.	*Per cent.*	*Per cent.*
Bread No. 53	44.63	44.68	44.46
Bread No. 62	49.15	49.39	49.35
Bread No. 70	47.19	46.71	47.02

The figures for ether extract of the breads reported on in this bulletin are those obtained from analyses of the flours from which the breads were made, calculated on the dry-matter basis. Considerably less ether extract was obtained in the analysis of the breads than from the flours used, even when the breads were dried at 70° C. But it is believed that the figures for the flours represent the actual fat content of the breads more nearly than those obtained by analysis of the breads, because, as shown in previous publications,[1] the fat in the flour does not appear to be volatilized in the making of the bread but simply rendered nonextractable in ether. The heat of combustion as calculated by factors agreed with that determined by the calorimeter much more closely when the figures for fat in the flour were used instead of those obtained by extraction of the bread. However, any error that might be introduced because of lack of accurate values for ether extract in the bread would not affect the accuracy of the experiments as regards available energy, because the values for energy in both the food and the feces are those determined by use of the bomb calorimeter.

The following table gives a comparison of the heats of combustion of several samples of bread dried in a water oven at 70° C., and over a water bath.

Table 5.—*Heats of combustion of bread dried in different ways.*

Sample.	Dried in water oven at 70° C.	Dried over water bath.
	Calories per gram.	*Calories per gram.*
Bread No. 53	4.385	4.305
Bread No. 62	4.405	4.421
Bread No. 70	4.365	4.402
Bread No. 77	4.385	4.422
Bread No. 81	4.305	4.299
Bread No. 85	4.288	4.240

[1] U. S. Dept. Agr., Office of Experiment Stations Buls. 35, p. 16; 67, pp. 32, 42–51.

In the digestion experiments the mixed milk of the experiment station herd was used. At each meal a sample of 50 cubic centimeters of the milk was put into a glass-stoppered bottle containing 100 milligrams of potassium bichromate. This preserved the samples in excellent condition for analysis. It had been found by experiment that potassium bichromate has no effect upon the determination of lactose by the polarization method. The sum of the protein, fat, carbohydrates, and ash obtained by direct determination was taken as the total solid matter in the milk. This was found to differ by 0.1 to 0.15 per cent from the total solids obtained by evaporation. The nitrogen was determined by the Kjeldahl method, the fat by the Adams gravimetric method, the sugar by polarization, and the ash by incineration at low temperature. For the determination of the heat of combustion 4 cubic centimeters of milk was evaporated to dryness in one of the small platinum capsules used in the bomb calorimeter. The amount of solid thus obtained was weighed and then burned. The heat of combustion of the milk was also calculated by use of the following factors: Protein, 5.880; fat, 9.321, and lactose, 3.736 calories per gram.

The digestibility of the food is measured by the difference between the total nutrients consumed in the food and those rejected in the feces; but not all the material in the feces is undigested residue from the food. A considerable portion of it is metabolic products.[1] In analyzing the feces in these experiments the nitrogen in the ether extract of several samples was determined and was found to range from 0.05 to 0.145 per cent. It was considered to be metabolic nitrogen.

The crude fiber in the feces from the entire-wheat and graham breads was determined, but is not reported. The amount was slightly in excess of that in the food, probably owing to the presence in the feces of some material other than true crude fiber, which was insoluble in dilute acid or alkali. Mann[2] found that the material ordinarily estimated as crude fiber contained some nitrogen, due to the presence of elastin and other nitrogenous bodies.

In Table 6 below is given the composition of the food, and in Table 7 that of the feces, in the series of digestion experiments. These tables also include similar data for experiments reported on later pages of the bulletin. The data for the feces are calculated to the water-free basis, since the amount of water in the fresh feces has no bearing upon the results of the digestion experiments. As mentioned on a preceding page, protein is calculated in the following tables by the use of the factor 6.25 instead of 5.70, in order that the results of the experiments may be directly compared with those of experiments previously reported.

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[1] U. S. Dept. Agr., Office of Experiment Stations Bul. 85, p. 33.

[2] Arch. Hyg., 36 (1899), p. 158.

TABLE 6.—*Composition of food materials used in digestion experiments.*

Sample No.	Material.	Water.	Protein (N×6.25).	Fat.	Carbohydrates.	Ash.	Heat of combustion per gram. Determined.	Heat of combustion per gram. Calculated.
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Calories.*	*Calories.*
	Bread, crumb, made from:							
53	Standard patent flour	44.13	7.75	0.90	46.90	0.32	2.450	2.503
62	Entire-wheat flour	49.16	7.45	1.14	41.73	.52	2.166	2.291
70	Graham flour	47.20	7.76	1.27	42.82	.95	2.060	2.367
77	Standard patent flour	44.89	7.58	.88	46.35	.30	2.417	2.468
81	Second patent flour	42.10	7.75	.72	49.16	.27	2.492	2.581
85	First patent flour	44.40	7.48	.71	47.14	.27	2.384	2.480
54	Milk, composite sample	86.52	3.15	4.63	5.00	.70	.792	.803
61	do	86.88	3.09	4.27	5.00	.76	.772	.767
69	do	87.61	2.95	3.50	5.15	.79	.716	.692
78	do	86.27	3.13	4.82	5.00	.78	.806	.820
82	do	86.86	3.12	4.27	5.00	.75	.775	.768
86	do	86.18	3.30	4.63	5.15	.74	.802	.818
103	Bread	38.50	8.35	.14	52.56	.45	2.598	2.705
116	do	38.10	8.36	.12	52.99	.43	2.601	2.723
118	do	37.50	8.40	.10	53.57	.43	2.637	2.746
131	do	34.64	6.96	.11	57.73	.56	2.713	2.839
140	do	36.25	8.51	.10	54.70	.44	2.690	2.800
102	Milk	87.29	3.02	4.17	4.72	.80	.762	.742
115	do	88.03	2.72	3.72	4.68	.85	.672	.681
117	do	87.51	3.10	3.92	4.65	.82	.728	.721
129	do	87.01	2.94	4.33	4.88	.84	.755	.759
130	do	87.36	3.02	3.95	4.92	.75	.734	.730
138	do	87.01	3.04	4.23	4.99	.73	.736	.760
139	do	87.48	2.96	3.91	4.92	.73	.727	.722
147	Flour	12.05	12.72	1.54	73.24	.45	3.840	3.957
149	do	11.79	12.00	1.18	74.63	.40	....	....
101	Rolled oats	8.66	14.69	6.96	67.89	1.80	4.560	4.351
100	Wheat starch	5.57	.72	.14	93.26	.31	3.903	3.972

TABLE 7.—*Composition of dry matter of feces.*

Sample No.	Material.	Protein (N×6.25).	Ether extract.	Nitrogen in ether extract.	Carbohydrates.	Ash.	Heat of combustion per gram.
	FECES.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Calories.*
55	Experiment No. 161	25.88	18.23	0.092	29.54	26.35	5.083
56	Experiment No. 162	28.12	21.46	.145	26.37	24.05	5.166
57	Experiment No. 163	26.75	18.92	.118	27.76	26.57	4.805
63	Experiment No. 165	23.56	15.15	.100	36.74	24.55	4.573
64	Experiment No. 166	22.75	17.63	.120	40.17	19.45	4.941
65	Experiment No. 167	25.25	15.05	.120	37.82	21.88	4.565
71	Experiment No. 170	18.13	10.45	.060	55.12	16.30	4.355
72	Experiment No. 171	18.13	10.52	.050	53.72	17.63	4.312
73	Experiment No. 172	23.12	11.27	.090	47.69	17.92	4.706
79	Experiment No. 169	22.88	18.39	....	33.64	25.09	4.839
83	Experiment No. 168	26.56	16.44	....	26.80	30.20	4.570
87	Experiment No. 164	23.63	16.14	....	28.52	31.71	4.988
107	Experiment No. 173	34.55	18.56	....	24.03	[illegible]	5.147
108	Experiment No. 174	28.31	12.63	....	42.59	16.47	4.682
109	Experiment No. 175	24.79	18.32	....	41.80	15.09	5.355
113	Experiment No. 176	29.23	25.73	....	27.51	17.53	5.250
114	Experiment No. 177	33.56	26.04	....	22.87	17.53	5.184
126	Experiment No. 178	29.55	14.70	....	36.75	19.00	4.931
127	Experiment No. 179	29.25	13.40	....	35.02	22.33	5.323
128	Experiment No. 180	32.31	14.75	....	34.68	18.26	5.303
121	Experiment No. 181	27.81	25.78	....	25.22	21.19	5.173
122	Experiment No. 182	29.19	22.40	....	29.60	18.81	5.124
132	Experiment No. 183	25.88	15.04	....	31.45	27.63	4.837
134	Experiment No. 184	30.94	11.53	....	30.93	26.60	4.812
133	Experiment No. 185	30.38	18.38	....	33.39	17.85	5.180
144	Experiment No. 186	23.69	12.10	....	37.85	26.36	4.837
145	Experiment No. 187	26.13	11.40	....	35.49	26.98	4.344
146	Experiment No. 188	22.19	14.54	....	36.77	26.50	5.037

In connection with the digestion experiments the urine was analyzed in order to obtain data for calculating the balance of income and outgo of nitrogen and relation of nitrogen to energy in the urine. In some samples the phosphoric and sulphuric acids were determined. For the former two methods were used, namely, (1) that adopted by the Association of Official Agricultural Chemists,[1] and (2) the uranium acetate method. The sulphuric acid was determined by precipitation with barium chlorid. The heat of combustion of the urine was determined by evaporating 10 cubic centimeters of urine, a little at a time, in one of the platinum dishes used for holding the substance to be burned in the bomb calorimeter. With the exception of the heat of combustion, which was usually determined in triplicate, duplicate determinations were made in all of the samples of urine. When the results did not agree closely, as was sometimes the case, three or four determinations were made.

The analyses reported in the table below are the averages of the different determinations.

TABLE 8.—*Composition of urine.*

Sample No.	Material.	Total amount voided.	Specific gravity.	Nitrogen.	Phosphoric acid (P_2O_5). Uranium acetate method.	Phosphoric acid (P_2O_5). Gravimetric method.	Sulphuric acid (SO_3).	Heat of combustion per gram determined.
	URINE.	*Grams.*		*Per cent.*	*Per cent.*	*Per cent.*	*Calories.*	*Calories.*
58	Experiment No. 161	1,417.7	1.028	1.79	0.37	0.33	0.12	0.122
59	Experiment No. 162	1,390.3	1.029	1.82	.35	.33	.18	.121
60	Experiment No. 163	2,035.5	1.022	1.43	.26	.26	.13	.117
66	Experiment No. 165	1,330.0	1.029	2.00	.37	.38	.19	.114
67	Experiment No. 166	1,404.0	1.031	1.98	.37		.21	.113
68	Experiment No. 167	1,669.0	1.026	1.76	.34	.37	.15	.105
74	Experiment No. 170	1,461.5	1.029	1.95	.34	.34	.22	.114
75	Experiment No. 171	1,662.3	1.026	1.59	.32	.31	.20	.109
76	Experiment No. 172	2,014.5	1.025	1.72	.35	.37	.23	.101
80	Experiment No. 169	2,077.0	1.023	1.48			.19	.098
84	Experiment No. 168	1,786.0	1.026	1.88	.30		.18	.115
88	Experiment No. 164	1,416.0		1.75				.105
104	Experiment No. 173	2,763.0	1.027	1.53				.132
105	Experiment No. 174	3,463.0	1.014	.82				.096
106	Experiment No. 175	3,554.0	1.022	1.19				.132
111	Experiment No. 176	4,375.0	1.016	.84				.083
112	Experiment No. 177	3,349.0	1.016	.93				.113
123	Experiment No. 178	1,949.0	1.028	1.57				.131
124	Experiment No. 179	2,414.0	1.015	.81				.090
125	Experiment No. 180	1,960.0	1.027	1.50				.140
119	Experiment No. 181	2,122.0	1.019	.96				.084
120	Experiment No. 182	1,501.0	1.031	1.54				.113
135	Experiment No. 183	2,221.0	1.025	1.55				.122
137	Experiment No. 184	2,060.0	1.015	.83				.085
136	Experiment No. 185	1,574.0	1.027	1.64				.138
141	Experiment No. 186	2,283.0	1.023	1.64				.128
142	Experiment No. 187	2,029.0	1.016	.94				.095
143	Experiment No. 188	2,480.0	1.028	1.98				.100

On pages 23 to 34 the results of digestion experiments Nos. 161–172 are recorded. Some explanation of the way the results were obtained seems desirable.

The amounts of protein, fat, and carbohydrates in each food material and in the feces were calculated from the total weight of each mat- -em

[1] U. S. Dept. Agr., Division of Chemistry Bul. 46.

and its composition as given in Tables 6 and 7. The heats of combustion of the bread, of the milk, and of the total feces, shown in the last column of the table, were calculated from the total weight of food material or feces and the heat of combustion of 1 gram of the material as determined by burning in the bomb calorimeter. The differences between the total nutrients in the food eaten and those rejected in the feces are taken as a measure of the total amounts digested, or the amounts which the body can use. The feces do not consist entirely of undigested residues, but contain a relatively large amount of metabolic products, as already stated (p. 17). These, however, are no longer useful to the body. The amounts of nutrients rejected in the feces, while not strictly representing the undigested portion of the food, do represent approximately the portion which the body[1] can not use and is consequently not available to the body for building tissue or yielding energy. Since the metabolic products in the feces represent material that has been digested, the common usage of taking the difference between food and feces as representing the digestible portion of the food is not wholly accurate. Atwater has suggested the use of the term availability for this purpose.

While the digestible or available portion of the different nutrients represents the amount which the body can utilize for the purposes of nutrition, the corresponding value for the heat of combustion of the food does not represent the actual amount of energy which the body obtains from the food absorbed from the alimentary canal, because of the incomplete combustion of protein in the body. When protein is burned in the bomb calorimeter the carbon in it is oxidized to carbon dioxid and the hydrogen to water, while the nitrogen is left in the free state; when protein is burned in the body, however, the oxidation is not so complete. The nitrogen is excreted by the kidneys, in combination with small amounts of carbon, hydrogen, and oxygen in the form of urea, uric acid, and allied compounds. In estimating the actual fuel values of the digestible nutrients of food, allowance must be made for these incompletely oxidized products. Of these urea is the most abundant, and it has been frequently assumed that all the nitrogen excreted in the urine is thus combined, and the allowance made has been that of the heat of combustion of an amount of urea corresponding to the amount of nitrogen found in the urine. According to this assumption 0.87 calorie of the energy latent in each gram of digestible protein would be lost to the body in the urea formed from the nitrogen of the protein.[2] In a considerable number of actual determinations of the ratio

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[1] See discussion of this subject by W. O. Atwater and associates in Connecticut Storrs Sta. Rpts. 1896, p. 166; 1897, p. 156, and 1899, p. 69.

[2] Urea contains 46.67 per cent nitrogen and has a heat of combustion of 2.54 calo- ...n. One gram of protein (16 per cent nitrogen) would yield (16 ÷ 46.67 =) ..., with a heat of combustion of (2.54 × 0.343=) 0.87.

of nitrogen to heat of combustion in urine of healthy men made by Atwater and his associates, the average heat of combustion of the organic matter in urine corresponding to 1 gram of digestible protein amounted to 1.25 calories.[1] From the data for the urine analyzed in the experiments here reported the factor for the ratio of protein ($N \times 6.25$) to energy in urine was calculated for each experiment. In many cases this was found to be low, suggesting that possibly there was a decomposition of the urine and a loss of some of the organic matter before the heat of combustion was determined, although determinations were made as soon as possible to avoid decomposition. The heat of combustion of the urine for each experiment is given in the paragraph following the table, but because of the variations noted it was deemed advisable to use throughout all the tables a uniform factor for the calculation of the energy of the digestible protein which is carried away in the unoxidized organic matter of the urine, and which therefore is not available to the body. In the following tables the figures given for the proportion of the energy in the food eaten, that is actually available to the body, are obtained, therefore, by deducting from the total energy of the digested food the energy lost to the body in organic matter of the urine. This latter value is determined by multiplying the total amount of digestible protein by 1.25.

The results actually obtained in these experiments are the values for the digestibility of a mixed diet consisting of bread and milk. In order to calculate the digestibility of the bread alone certain more or less arbitrary factors were assumed. From the results of a considerable number of digestion experiments made in this country and in Europe it was assumed that 97 per cent of the protein, 95 per cent of the fat, and 98 per cent of the carbohydrates of the milk were digestible.[2] Since these same factors are applied alike to all of the experiments, the final results are strictly comparable.

As an illustration, the method of calculating the digestibility of bread may be explained by applying these factors to the results of experiment No. 161. In this experiment there was a total of 123 grams of protein consumed in the two days, of which 63 grams was furnished by the milk. If 97 per cent of the protein of the milk is digestible, there would be 1.9 grams undigested milk protein left in the feces, which, subtracted from the total 9.9 grams of protein ($N \times 6.25$) in the feces, would leave 8 grams as coming from the undigested or unavailable portion of the bread. Subtracting the 8 grams of protein in the feces from bread from the 60 grams of protein in the bread consumed, leaves 52 grams as the amount of digestible protein in the bread. The proportion of the protein in the total food that is digestible is found by dividing the total protein digested by the total protein consumed ($113.1 \div 123 = 92.0$). Likewise, the coefficient of digestibility of protein

[1] Connecticut Storrs Sta. Rpt. 1899, p. 100.
[2] Connecticut Storrs Sta. Rpt. 1899, p. 104.

in bread alone is found by dividing the digestible protein in bread, 52 grams, by the total protein consumed in bread, 60 grams, giving 86.7 per cent. The coefficients of digestibility of the fat and carbohydrates of the bread are computed in a similar manner. In the tables of several of the following experiments the results obtained for the digestibility of the fat in the bread are not given because they could not be satisfactorily determined by the method employed. This is doubtless due to the fact that, the amount of fat in the bread being very small in proportion to the total fat in the diet, slight differences in the digestibility of fat in milk above or below the factor assumed in these computations have relatively large effects upon the results for digestibility of fat in the bread, while errors due to metabolic products are also proportionately larger. However, for the sake of computing the energy of the digestible nutrients in the bread in those tables where the digestible fat in bread is not given, it was assumed that 90 per cent of the fat in the bread was digested.

As previously stated, the amounts of energy given for the bread and milk and the total feces were determined from the total weight of each material and its heat of combustion per gram as determined by the bomb calorimeter. In order to estimate the amounts of energy in the feces from bread alone, the following factors were used: Protein, 5.65; fat, 9.4; and carbohydrates, 4.15 calories per gram. The heat of combustion of the total feces as computed by use of these factors was usually smaller (though in some cases it was larger) than the values determined with the calorimeter. For the calculations of the heats of combustion of feces from bread and from food other than bread it was assumed that the ratio of the computed heats of combustion of the total feces to the heats of combustion actually determined was the same as the ratio of the computed heats of combustion of the feces from bread, or from food other than bread, to the actual values for the same. For example, in experiment No. 161 the heat of combustion of the total feces as computed by the above factors was 169 calories, while the heat of combustion as actually determined was 194 calories. The computed heat of combustion of the feces from food other than bread was 61 calories; therefore the actual value was assumed to be (169 : 194 :: 61 : 70) 70 calories. Similarly, the computed heat of combustion of the feces from bread was 108 calories; and the actual value was assumed to be (169 : 194 :: 108 : 124) 124 calories.

The amount of the energy of the total food which was lost in the organic matter of the urine was obtained in experiment No. 161 by multiplying the digestible protein in the food (123 grams) by the factor representing the energy lost in the urine (1.25 calories per gram). In a similar manner the digestible protein in the bread alone (52 grams) multiplied by 1.25 gave the amount of energy of the bread which was

eliminated in the organic matter of the urine. The proportion of the energy in the total food which was actually available to the body was found by dividing the energy of the food digested (3,286 calories) minus the energy lost in the urine ($123 \times 1.25 = 154$ calories) by the energy in the total food (3,480 calories). The proportion of energy in the bread which is actually available is obtained in a like manner by dividing the difference between the estimated energy in the bread digested (1,771 calories) and the energy lost in the urine ($52 \times 1.25 = 65$ calories) by the total energy in the bread consumed (1,895 calories).

The details of this series of experiments are given in the following tables (Nos. 9–20). Following the tabular details of each experiment is a paragraph showing the nitrogen balance in the particular instance. i. e., whether the subject gained or lost nitrogen during the two days of the experiment.

DIGESTION EXPERIMENT NO. 161.

Kind of food.—Bread, made from standard patent flour, and milk.

Subject.—Student No. 1; 27 years of age. One-half of his time was spent in ordinary farm labor and the other half at university work.

Weight.—At the beginning of the experiment, 159 pounds; at the close, 157 pounds.

Duration.—Two days, with six meals, beginning with breakfast, April 5, 1899.

TABLE 9.—*Results of digestion experiment No. 161.*

Sample No.		Weight of material.	Protein (N×6.25).	Fat.	Carbohydrates.	Ash.	Heat of combustion.
	Food consumed:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
53	Bread	773.5	60.0	6.9	362.8	2.5	1,895
54	Milk	2,000.0	63.0	92.6	100.0	14.0	1,585
	Total		123.0	99.5	462.8	16.5	3,480
55	Feces (water-free)	38.2	9.9	7.0	11.3	10.1	194
	Estimated feces from food other than bread		1.9	4.6	2.0		70
	Estimated feces from bread		8.0	2.4	9.3		124
	Total amount digested		113.1	92.5	451.5	6.4	3,286
	Estimated digestible nutrients in bread		52.0	4.5	353.5		1,771
	Coefficients of digestibility of total food		*Per ct.* 92.0	*Per ct.* 93.0	*Per ct.* 97.5	*Per ct.* 38.8	*Per ct.* 94.4
	Estimated coefficients of digestibility of bread		86.7	65.2	97.4		93.5
	Proportion of energy actually available to body:						
	In total food						90.4
	In bread alone						90.0

During this experiment the subject eliminated 1,414.7 grams urine, containing 1.79 per cent, or 25.3 grams, nitrogen. The average nitrogen balance per day was therefore as follows: Income in food, 9.9 grams; outgo in urine 12.2 grams, and in feces 0.8 gram; implying a loss of 3.1 grams nitrogen, corresponding to 19.4 grams protein. The total heat combustion of the urine as determined was 173 calories.

DIGESTION EXPERIMENT NO. 162.

Kind of food.—Bread, made from standard patent flour, and milk.

Subject.—Student No. 2; 24 years of age, with average amount of exercise.

Weight.—At the beginning of the experiment, 140 pounds; at the close, 139 pounds.

Duration.—Two days, with six meals, beginning with breakfast, April 5, 1899.

TABLE 10.—*Results of digestion experiment No. 162.*

Sample No.		Weight of material.	Protein (N×6.25).	Fat.	Carbohydrates.	Ash.	Heat of combustion.
	Food consumed:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
53	Bread	876.0	67.9	7.8	410.9	2.8	2,146
54	Milk	2,100.0	66.2	97.2	105.0	14.7	1,664
	Total		134.1	105.0	515.9	17.5	3,810
56	Feces (water-free)	40.3	11.3	8.6	10.6	9.7	208
	Estimated feces from food other than bread		2.0	4.9	2.1		72
	Estimated feces from bread		9.3	3.7	8.5		136
	Total amount digested		122.8	96.4	505.3	7.8	3,602
	Estimated digestible nutrients in bread		58.6	4.1	402.4		2,010
	Coefficients of digestibility of total food		*Per ct.* 91.6	*Per ct.* 91.8	*Per ct.* 97.9	*Per ct.* 44.6	*Per ct.* 94.5
	Estimated coefficients of digestibility of bread		86.3	52.6	97.9		93.7
	Proportion of energy actually available to body:						
	In total food						90.5
	In bread alone						90.8

During this experiment the subject eliminated 1,390.3 grams urine, containing 1.82 per cent, or 25.3 grams, nitrogen. The average nitrogen balance per day was therefore as follows: Income in food, 10.8 grams; outgo in urine, 12.7 grams, and in feces, 0.9 gram; implying a loss of 2.8 grams nitrogen, corresponding to 17.5 grams protein. The total heat of combustion of the urine as determined was 168 calories.

DIGESTION EXPERIMENT NO. 163.

Kind of food.—Bread, made from standard patent flour, and milk.

Subject.—Man No. 3; 24 years of age; employed at moderate farm labor one-half of the time; the other half given to office work

Weight.—At beginning of experiment, 166 pounds; at the close, 163 pounds.

Duration.—Two days, with six meals, beginning with breakfast, April 5, 1899.

TABLE 11.—*Results of digestion experiment No. 163.*

Sample No.		Weight of material.	Protein (N×6.25).	Fat.	Carbohydrates.	Ash.	Heat of combustion.
	Food consumed:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
53	Bread	868.7	67.4	7.8	407.4	2.8	2,128
54	Milk	2,680.0	84.4	124.1	134.0	18.8	2,123
	Total		151.8	131.9	541.4	21.6	4,251
57	Feces (water-free)	52.6	14.1	10.0	14.6	14.0	253
	Estimated feces from food other than bread		2.5	6.2	2.7		88
	Estimated feces from bread		11.6	3.8	11.9		165
	Total amount digested		137.7	121.9	526.8	7.6	3,998
	Estimated digestible nutrients in bread		55.8	4.0	395.5		1,963
	Coefficients of digestibility of total food		*Per ct.* 90.7	*Per ct.* 92.4	*Per ct.* 97.3	*Per ct.* 35.2	*Per ct.* 94.0
	Estimated coefficients of digestibility of bread		82.8	51.3	97.1		92.3
	Proportion of energy actually available to body:						
	In total food						90.0
	In bread alone						89.5

During this experiment the subject eliminated 2,035.5 grams urine, containing 1.43 per cent, or 29.1 grams, nitrogen. The average nitrogen balance per day was therefore as follows: Income in food, 12.1 grams; outgo in urine, 14.6 grams, and in feces, 1.2 grams; implying a loss of 3.7 grams nitrogen, corresponding to 23.1 grams protein. The total heat of combustion of the urine as determined was 238 calories.

DIGESTION EXPERIMENT NO. 164.

Kind of food.—Bread, made from first patent flour, and milk.

Subject.—Man No. 4; 26 years of age; with office work and some light labor.

Weight.—At the beginning of the experiment, 157½ pounds; at the close, 156 pounds.

Duration.—Two days, with six meals, beginning with breakfast, April 9, 1899.

TABLE 12.—*Results of digestion experiment No. 164.*

Sample No.		Weight of material.	Protein (N×6.25).	Fat.	Carbohydrates.	Ash.	Heat of combustion.
	Food consumed:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
85	Bread	871.5	65.2	6.2	410.8	2.4	2,078
86	Milk	3,700.0	122.1	171.3	190.6	27.4	2,967
	Total		187.3	177.5	601.4	29.8	5,045
87	Feces (water-free)	42.0	9.9	6.8	12.0	13.3	210
	Estimated feces from food other than bread		3.7		3.8		
	Estimated feces from bread		6.2		8.2		
	Total amount digested		177.4	170.7	589.4	16.5	4,835
	Estimated digestible nutrients in bread		59.0		402.6		
	Coefficients of digestibility of total food		*Per ct.* 94.7	*Per ct.* 96.2	*Per ct.* 98.0	*Per ct.* 55.4	*Per ct.* 95.8
	Estimated coefficients of digestibility of bread		90.5		98.0		*a* 96.4
	Proportion of energy actually available to body:						
	In total food						91.5
	In bread alone						*a* 92.8

a Computed by assuming that 90 per cent of the fat in the bread is digestible.

During this experiment the subject eliminated 1,416 grams urine, containing 1.75 per cent, or 24.8 grams, nitrogen. The average nitrogen balance per day was therefore as follows: Income in food, 15.0 grams; outgo in urine, 12.4 grams, and in feces, 0.8 gram; implying a gain of 1.8 grams nitrogen, corresponding to 11.2 grams protein. The total heat of combustion of the urine as determined was 149 calories.

DIGESTION EXPERIMENT NO. 165.

Kind of food.—Bread, made from entire-wheat flour, and milk.

Subject.—Student No. 1. This experiment was performed under conditions similar to those in experiment No. 161.

Weight.—At the beginning of the experiment, 158 pounds; at the close, 157 pounds.

Duration.—Two days, with six meals, beginning with breakfast, April 13, 1899.

TABLE 13.—*Results of digestion experiment No. 165.*

Sample No.		Weight of material.	Protein (N×6.25).	Fat.	Carbohydrates.	Ash.	Heat of combustion.
	Food consumed:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
62	Bread	866.0	64.5	9.9	361.4	4.5	1,939
61	Milk	3,030.0	93.6	129.4	151.5	23.0	2,339
	Total		158.1	139.3	512.9	27.5	4,278
63	Feces (water-free)	71.6	16.9	10.9	26.3	17.6	327
	Estimated feces from food other than bread		2.8	6.5	3.0		87
	Estimated feces from bread		14.1	4.4	23.3		240
	Total amount digested		141.2	128.4	486.6	9.9	3,951
	Estimated digestible nutrients in bread		50.4	5.5	338.1		1,699

TABLE 13.—*Results of digestion experiment No. 165*—Continued.

Sample No.		Weight of material.	Protein (N×6.25).	Fat.	Carbohydrates.	Ash.	Heat of combustion.
	Coefficients of digestibility of total food	....	*Per ct.* 89.3	*Per ct.* 92.2	*Per ct.* 94.9	*Per ct.* 36.0	*Per ct.* 92.4
	Estimated coefficients of digestibility of bread	....	78.1	55.6	93.5	....	87.6
	Proportion of energy actually available to body:						
	In total food	....	....	....	....	....	88.2
	In bread alone	....	....	....	....	....	84.4

During this experiment the subject eliminated 1,330 grams urine, containing 2 per cent, or 26.6 grams, nitrogen. The average nitrogen balance per day was therefore as follows: Income in food, 12.7 grams; outgo in urine, 13.3 grams, and in feces, 1.4 grams; implying a loss of 2 grams nitrogen, corresponding to 12.5 grams protein. The total heat of combustion of the urine as determined was 152 calories.

DIGESTION EXPERIMENT NO. 166.

Kind of food.—Bread, made from entire-wheat flour, and milk.

Subject.—Student No. 2. This experiment was performed under conditions similar to those in experiment No. 162.

Weight.—At the beginning of the experiment, 140 pounds; at the close, 138 pounds.

Duration.—Two days, with six meals, beginning with breakfast, April 13, 1899.

TABLE 14.—*Results of digestion experiment No. 166.*

Sample No.		Weight of material.	Protein (N×6.25).	Fat.	Carbohydrates.	Ash.	Heat of combustion.
	Food consumed:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
62	Bread	931.6	69.4	10.6	388.7	4.8	2,086
61	Milk	2,250.0	69.5	96.1	112.5	17.1	1,737
	Total	....	138.9	106.7	501.2	21.9	3,823
64	Feces (water-free)	58.3	13.3	10.3	23.4	11.3	288
	Estimated feces from food other than bread	....	2.1	4.8	2.3	....	70
	Estimated feces from bread	....	11.2	5.5	21.1	....	218
	Total amount digested	....	125.6	96.4	477.8	10.6	3,535
	Estimated digestible nutrients in bread	....	58.2	5.1	367.6	....	1,863
	Coefficients of digestibility of total food	....	*Per ct.* 90.4	*Per ct.* 90.4	*Per ct.* 95.3	*Per ct.* 48.4	*Per ct.* 92.5
	Estimated coefficients of digestibility of bread	....	83.9	48.1	94.6	....	89.6
	Proportion of energy actually available to body:						
	In total food	....	....	....	....	....	88.4
	In bread alone	....	....	....	....	....	86.1

During this experiment the subject eliminated 1,404 grams urine, containing 1.98 per cent, or 27.8 grams, nitrogen. The average nitrogen balance per day was therefore as follows: Income in food, 11.1 grams; outgo in urine, 13.9 grams, and in feces 1 gram; implying a loss of 3.8 grams nitrogen, corresponding to 23.7 grams protein. The total heat of combustion of the urine as determined was 159 calories.

DIGESTION EXPERIMENT NO. 167.

Kind of food.—Bread, made from entire-wheat flour, and milk.

Subject.—Man No. 3. This experiment was performed under conditions similar to those in experiment No. 163.

Weight.—At the beginning of the experiment, 169 pounds; at the close, 167 pounds.

Duration.—Two days with six meals, beginning with breakfast, April 13, 1899.

TABLE 15.—*Results of digestion experiment No. 167.*

Sample No.		Weight of material.	Protein (N×6.25).	Fat.	Carbohydrates.	Ash.	Heat of combustion.
	Food consumed:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
62	Bread	938.7	70.0	10.7	391.7	4.9	2,102
61	Milk	3,030.0	93.6	129.4	151.5	23.0	2,339
	Total		163.6	140.1	543.2	27.9	4,441
65	Feces (water-free)	68.8	17.4	10.4	26.0	15.1	314
	Estimated feces from food other than bread		2.8	6.5	3.0		90
	Estimated feces from bread		14.6	3.9	23.0		224
	Total amount digested		146.2	129.7	517.2	12.8	4,127
	Estimated digestible nutrients in bread		55.3	6.8	368.7		1,878
	Coefficients of digestibility of total food		*Per ct.* 89.3	*Per ct.* 92.6	*Per ct.* 95.2	*Per ct.* 45.9	*Per ct.* 92.9
	Estimated coefficients of digestibility of bread		79.1	63.6	94.1		89.4
	Proportion of energy actually available to body:						
	In total food						88.8
	In bread alone						86.1

During this experiment the subject eliminated 1,669 grams urine, containing 1.76 per cent, or 29.4 grams, nitrogen. The average nitrogen balance per day was therefore as follows: Income in food, 13.1 grams; outgo in urine, 14.7 grams, and in feces, 1.4 grams; implying a loss of 3 grams nitrogen, corresponding to 18.8 grams protein. The total heat of combustion of the urine as determined was 175 calories.

DIGESTION EXPERIMENT NO. 168.

Kind of food.—Bread, made from second patent flour, and milk.

Subject.—Man No. 4. This experiment was performed under conditions similar to those in experiments Nos. 164 and 169.

Weight.—At the beginning of the experiment, 156 pounds; at the close, 156 pounds.

Duration.—Two days, with six meals, beginning with breakfast, April 13, 1899.

TABLE 16.—*Results of digestion experiment No. 168.*

Sample No.		Weight of material.	Protein (N×6.25).	Fat.	Carbohydrates.	Ash.	Heat of combustion.
	Food consumed:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
81	Bread	927.5	71.9	6.7	455.9	2.5	2,312
82	Milk	3,470.0	108.3	148.2	173.5	26.0	2,689
	Total		180.2	154.9	629.4	28.5	5,001
83	Feces (water-free)	35.5	9.4	5.8	9.5	10.7	162
	Estimated feces from food other than bread		3.2		3.4		
	Estimated feces from bread		6.2		6.1		
	Total amount digested		170.8	149.1	619.9	17.8	4,839
	Estimated digestible nutrients in bread		65.7		449.8		
			Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
	Coefficients of digestibility of total food		94.8	96.3	98.5	62.5	96.8
	Estimated coefficients of digestibility of bread		91.4		98.7		*a* 97.1
	Proportion of energy actually available to body:						
	In total food						92.5
	In bread alone						*a* 93.5

a Calculated according to the assumption that 90 per cent of the fat in the bread is digestible.

During this experiment the subject eliminated 1,786 grams urine, containing 1.88 per cent, or 33.6 grams, nitrogen. The average nitrogen balance per day was therefore as follows: Income in food, 14.4 grams; outgo in urine, 16.8 grams, and in feces, 0.7 gram; implying a loss of 3.1 grams nitrogen, corresponding to 19.4 grams protein. The total heat of combustion of the urine as determined was 205 calories.

DIGESTION EXPERIMENT NO. 169.

Kind of food.—Bread, made from standard patent flour, and milk.

Subject.—Man No. 4. This experiment was performed under conditions similar to those in experiments Nos. 164 and 168.

Weight.—At the beginning of the experiment, 156 pounds; at the close, 156 pounds.

Duration.—Two days, with six meals, beginning with breakfast, April 16, 1899.

TABLE 17.—*Results of digestion experiment No. 169.*

Sample No.		Weight of material.	Protein (N×6.25).	Fat.	Carbohydrates.	Ash.	Heat of combustion.
	Food consumed:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
77	Bread	886.7	67.2	7.8	411.0	2.6	2,143
78	Milk	3,775.0	118.2	182.0	188.8	29.5	3,043
	Total		185.4	189.8	599.8	32.1	5,186
79	Feces (water-free)	43.5	10.0	8.0	14.6	10.9	211
	Estimated feces from food other than bread		3.5		3.8		
	Estimated feces from bread		6.5		10.8		
	Total amount digested		175.4	181.8	585.2	21.2	4,975
	Estimated digestible nutrients in bread		60.7		400.2		

TABLE 17.—*Results of digestion experiment No. 169*—Continued.

Sample No.		Weight of material.	Protein (N×6.25).	Fat.	Carbohydrates.	Ash.	Heat of combustion.
	Coefficients of digestibility of total food		*Per ct.* 94.6	*Per ct.* 95.8	*Per ct.* 97.6	*Per ct.* 65.0	*Per ct.* 95.9
	Estimated coefficients of digestibility of bread		90.3		97.4		*a*95.8
	Proportion of energy actually available to body:						
	In total food						97.1
	In bread alone						*a*92.2

a Calculated according to the assumption that 90 per cent of the fat in the bread is digestible.

During this experiment the subject eliminated 2,077 grams urine, containing 1.48 per cent, or 30.7 grams, nitrogen. The average nitrogen balance per day was therefore as follows: Income in food 14.9 grams; outgo in urine, 15.4 grams, and in feces 0.8 gram; implying a loss of 1.3 grams nitrogen, corresponding to 8.1 grams protein. The total heat of combustion of the urine as determined was 204 calories.

DIGESTION EXPERIMENT NO. 170.

Kind of food.—Bread, made from graham flour, and milk.

Subject.—Student No. 1. This experiment was performed under conditions similar to those in experiment No. 161.

Weight.—At the beginning of the experiment, 159 pounds; at the close, 155 pounds.

Duration.—Two days, with six meals, beginning with breakfast. April 24, 1899.

TABLE 18.—*Results of digestion experiment No. 170.*

Sample No.		Weight of material.	Protein (N×6.25).	Fat.	Carbohydrates.	Ash.	Heat of combustion.
	Food consumed:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
70	Bread	908.3	70.5	11.5	389.0	8.6	2,093
69	Milk	3,250.0	95.9	113.8	167.4	25.7	2,327
	Total		166.4	125.3	556.4	34.3	4,420
71	Feces (water-free)	90.0	16.3	9.4	49.6	14.7	392
	Estimated feces from food other than bread		2.9	5.7	3.3		83
	Estimated feces from bread		13.4	3.7	46.3		309
	Total amount digested		150.1	115.9	506.8	19.6	4,028
	Estimated digestible nutrients in bread		57.1	7.8	342.7		1,784
	Coefficients of digestibility of total food		*Per ct.* 90.2	*Per ct.* 92.5	*Per ct.* 91.1	*Per ct.* 57.1	*Per ct.* 91.1
	Estimated coefficients of digestibility of bread		81.0	67.8	88.1		85.2
	Proportion of energy actually available to body:						
	In total food						86.9
	In bread alone						81.8

During this experiment the subject eliminated 1,46[illegible]5 grams urine, containing 1.95 per cent, or 28.5 grams, nitrogen. Th[illegible]erage nitrogen balance per day was therefore as follows: Inco[illegible] food, 13.3

grams; outgo in urine, 14.3 grams, and in feces 1.3 grams; implying a loss of 2.3 grams nitrogen, corresponding to 14.4 grams protein. The total heat of combustion of the urine as determined was 167 calories.

DIGESTION EXPERIMENT NO. 171.

Kind of food.—Bread, made from graham flour, and milk.

Subject.—Student No. 2. This experiment was performed under conditions similar to those in experiment No. 162.

Weight.—At the beginning of the experiment, 140 pounds; at the close, 139 pounds.

Duration.—Two days, with six meals, beginning with breakfast, April 24, 1899.

TABLE 19.—*Results of digestion experiment No. 171.*

Sample No.		Weight of material.	Protein (N×6.25).	Fat.	Carbohydrates.	Ash.	Heat of combustion.
	Food consumed:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
70	Bread	1,020.8	79.2	12.9	437.2	9.7	2,353
69	Milk	2,500.0	73.8	87.5	128.8	19.8	1,790
	Total	....	153.0	100.4	566.0	29.5	4,143
72	Feces (water-free)	97.0	17.6	10.2	52.1	17.1	418
	Estimated feces from food other than bread	....	2.2	4.4	2.6	....	64
	Estimated feces from bread	....	15.4	5.8	49.5	....	354
	Total amount digested	....	135.4	90.2	513.9	12.4	3,725
	Estimated digestible nutrients in bread	....	63.8	7.1	387.7	....	1,999
			Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
	Coefficients of digestibility of total food	....	88.5	89.8	90.8	42.0	89.9
	Estimated coefficients of digestibility of bread	....	80.6	55.1	88.7	....	85.0
	Proportion of energy actually available to body:						
	In total food	....	....	....	....	....	85.8
	In bread alone	....	....	....	....	....	81.6

During this experiment the subject eliminated 1,662.3 grams urine, containing 1.59 per cent, or 26.4 grams, nitrogen. The average nitrogen balance per day was therefore as follows: Income in food, 12.3 grams; outgo in urine, 13.2 grams, and in feces 1.4 grams; implying a loss of 2.3 grams nitrogen, corresponding to 14.4 grams protein. The total heat of combustion of the urine as determined was 181 calories.

DIGESTION EXPERIMENT NO. 172.

Kind of food.—Bread, made from graham flour, and milk.

Subject.—Man No. 3. This experiment was performed under conditions similar to those in experiment No. 163.

Weight.—At the beginning of the experiment, 168 pounds; at the close, 166 pounds.

Duration.—Two days, with six meals, beginning with breakfast, April 24, 1899.

TABLE 20.—*Results of digestion experiment No. 172.*

Sample No.		Weight of material.	Protein (N×6.25).	Fat.	Carbohydrates.	Ash.	Heat of combustion.
	Food consumed:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
70	Bread	1,274.4	98.9	16.2	545.8	12.1	2,937
69	Milk	4,550.0	134.2	159.3	234.3	35.9	3,258
	Total		233.1	175.5	780.1	48.0	6,195
73	Feces (water-free)	141.1	32.6	15.9	67.3	25.3	664
	Estimated feces from food other than bread		4.0	8.0	4.7		124
	Estimated feces from bread		28.6	7.9	62.6		540
	Total amount digested		200.5	159.6	712.8	22.7	5,531
	Estimated digestible nutrients in bread		70.3	8.3	483.2		2,397
	Coefficients of digestibility of total food		*Per ct.* 86.0	*Per ct.* 91.0	*Per ct.* 91.4	*Per ct.* 47.3	*Per ct.* 89.3
	Estimated coefficients of digestibility of bread		71.1	51.2	88.5		81.6
	Proportion of energy actually available to body:						
	In total food						85.2
	In bread alone						78.6

During this experiment the subject eliminated 2,014.5 grams urine, containing 1.72 per cent, or 34.7 grams, nitrogen. The average nitrogen balance per day was therefore as follows: Income in food, 18.7 grams; outgo in urine, 17.4 grams, and in feces, 2.6 grams; implying a loss of 1.3 grams nitrogen, corresponding to 8.1 grams protein. The total heat of combustion of the urine as determined was 203 calories.

In the following table are summarized the results obtained in the experiments for the digestibility of the total diet:

TABLE 21.—*Summary of digestion experiments Nos. 161 to 172, digestibility of nutrients and availability of energy of total food.*

Experiment No.	Subject No.	Kind of food.	Protein.	Fat.	Carbohydrates.	Energy.
			Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
161	1	White bread (standard patent)	92.0	93.0	97.5	90.4
162	2	.....do	91.6	91.8	97.9	90.5
163	3	.....do	90.7	92.4	97.3	90.0
		Average of 3	91.4	92.4	97.6	90.3
165	1	Entire-wheat bread	89.3	92.2	94.9	88.2
166	2	.....do	90.4	90.4	95.3	88.4
167	3	.....do	89.3	92.6	95.2	88.8
		Average of 3	89.7	91.7	95.1	88.5
170	1	Graham bread	90.2	92.5	91.1	86.9
171	2	.....do	88.5	89.8	90.8	85.8
172	3	.....do	86.0	91.0	91.4	85.2
		Average of 3	88.2	91.1	91.1	86.0
164	4	White bread (first patent)	94.7	96.2	98.0	91.5
168	4	White bread (second patent)	94.8	96.3	98.5	92.5
169	4	White bread (standard patent)	94.6	95.8	97.6	91.7
		Average of 3	94.7	96.1	98.0	91.9

The following table summarizes the results of the computed digestibility of the bread alone:

TABLE 22.—*Digestibility of nutrients and availability of energy of bread alone.*

Experiment No.	Subject No.	Kind of food.	Protein.	Fat.	Carbohydrates.	Energy.
			Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
161	1	White bread (standard patent)	86.7	65.2	97.4	90.0
162	2	.....do	86.3	52.6	97.9	90.8
163	3	.....do	82.8	51.3	97.1	89.5
		Average of 3	85.3	56.4	97.5	90.1
165	1	Entire-wheat bread	78.1	55.6	93.5	84.4
166	2	.....do	83.9	48.1	94.6	86.1
167	3	.....do	79.1	63.6	94.1	86.1
		Average of 3	80.4	55.8	94.1	85.5
170	1	Graham bread	81.0	67.8	88.1	81.8
171	2	.....do	80.6	55.1	88.7	81.6
172	3	.....do	71.1	51.2	88.5	78.6
		Average of 3	77.6	58.0	88.4	80.7
164	4	White bread (first patent)	90.5	....	98.0	92.8
168	4	White bread (second patent)	91.4	....	98.7	93.5
169	4	White bread (standard patent)	90.3	....	97.4	92.2
		Average of 3	90.7	....	98.0	92.8

Assuming that the averages for bread of different kinds given in the above table represent also the coefficients of digestibility of the nutrients in the different flours, the proportions of digestible nutrients in the flours may be calculated from their composition as given in Table 2. Thus standard patent flour contains 11.99 per cent protein, 85.3 per cent of which is digestible; the proportion of digestible protein in standard patent flour would then be (11.99 per cent × 85.3 =) 10.2 per cent. In like manner the digestible carbohydrates and available energy may be calculated. Such calculations have been made for standard patent flour, entire-wheat flour, and graham flour on the basis of the composition of the flour as milled. The following table shows the results, as well as the total protein and carbohydrates, in comparison with the proportions of the nutrients and energy in the different flours.

TABLE 23.—*Proportions of total and digestible nutrients and available energy in different grades of flour as milled.*

Flour.	Protein.				Carbohydrates.				Heat of combustion per gram.	
	N×5.70		N×6.25		N×5.70		N×6.25			
	Total.	Digestible.	Total.	Digestible.	Total.	Digestible.	Total.	Digestible.	Total.	Available.
	Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Calories*	*Calories.*
Standard patent	11.99	10.2	13.14	11.2	75.36	73.5	74.21	72.3	4.050	3.650
Entire wheat	12.26	9.9	13.44	10.8	73.67	69.3	72.49	68.2	4.030	3.445
Graham	12.65	9.8	13.86	10.7	74.99	66.3	73.78	65.2	4.150	3.350

From this table it will be observed that according to composition the graham flour contained the largest proportion of protein and the largest amount of energy, while the standard patent flour contained the smallest proportion of protein, but a little more energy than the entire-wheat flour. According to the results of the digestion experiments, however, the proportions of digestible protein and the amount of energy actually available to the body were greater in the standard patent flour than in the entire-wheat or the graham flour. The latter contained the least digestible protein and available energy.

In the three experiments with subject No. 4, in which first patent, second patent, and standard patent flours were used, the digestibility of these three flours was found to be practically the same. This will be observed from the results in Table 22.

It will also be noticed that the digestibility of the protein of the standard patent flour was somewhat greater with subject No. 4 than with either subject No. 1 or No. 2, while with subject No. 3 it was somewhat less. These differences are doubtless due largely to individual peculiarities of the different men.

A comparison of the feces from the different flours is also interesting. The feces from a given amount of graham and entire-wheat flour breads were more bulky, and weighed more than those from the same weight of standard patent flour bread. Pl. I shows the relative amounts of dry feces produced in two days from the different breads.

A microscopic examination of the feces of the various digestion experiments was made, with the following results: The feces from bread made from standard patent flour contained very small particles of disintegrated starch, which gave the color reaction with iodin. The feces from graham and entire-wheat breads contained masses of material containing wheat-starch grains in practically the same form as in the original graham and entire-wheat flour breads (Pl. II).

The comparatively small amount of digestible protein and available energy in the feces from the bread made from the patent flour as compared with the same nutrients from the entire wheat and graham flour bread is doubtless due to the fact that the patent flour is much more finely ground. Results of a similar general character were obtained in an experiment at the Minnesota Experiment Station,[1] when pigs were fed whole and ground wheat. The ground wheat was 10 per cent more digestible than the whole wheat. Other experiments with animals have shown that when foods are ground the nutrients are from 3.3 to 14 per cent more digestible than in unground foods.[2] Fineness of division of the particles, evidently, has a material influence upon the digestibility of a food.

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[1] Minnesota Sta. Bul. 36, p. 147.

[2] U. S. Dept. Agr., Office of Experiment Stations Bul. 77.

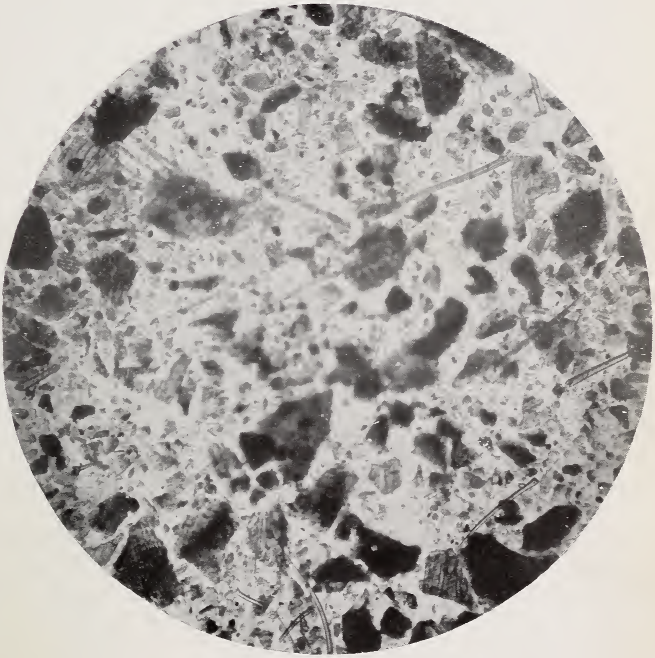
A *B* *C*

A, 307.7 grams of bread from 227 grams of graham flour; *B*, 302.5 grams of bread from 227 grams of entire-wheat flour; *C*, 301.5 grams of bread from 227 grams of standard patent flour.

A *B* *C*

A, Feces from graham bread; *B*, feces from entire-wheat bread; *C*, feces from standard patent bread.

BREAD MADE FROM ENTIRE-WHEAT, PATENT, AND GRAHAM FLOURS, AND CHARACTER OF FECES FROM SAME.



MICRO-PHOTOGRAPH SHOWING UNDIGESTED STARCH PARTICLES IN THE FECES FROM ENTIRE-WHEAT FLOUR.

ARTIFICIAL DIGESTION EXPERIMENTS WITH BREAD OF DIFFERENT KINDS.

Artificial digestion experiments are frequently made by treating samples of foods with digestive ferments under conditions of temperature, etc., approximating those of the body.[1] The results of such experiments are not absolute, but, it is believed, may be compared with each other when obtained by the same method. For purposes of comparison, samples of the breads from the different kinds of flour used in the experiments with men were digested artificially by means of an acid pepsin solution.[2] The proportion of dry matter and nitrogen in the samples used are shown in the following table:

TABLE 24.—*Dry matter and nitrogen in bread of different kinds.*

Sample No.	Kind of bread.	Dry matter.	Nitrogen.
		Per cent.	*Per cent.*
93	Bread from standard patent flour	58.90	2.22
94	Bread from entire-wheat flour	58.31	2.32
95	Bread from graham flour	56.68	2.37

In each artificial digestion experiment 25 grams of the bread (crumb only) was kept for four hours in 225 cubic centimeters of acid pepsin solution at a temperature of 38° C. The insoluble residue was filtered off, washed and dried, and the nitrogen content determined. The results of these experiments follow:

TABLE 25.—*Results of artificial digestion experiment with bread of different kinds.*

Sample No.	Kind of bread.	Nitrogen.		
		In bread.	In undigested residue.	Digested.
		Gram.	*Gram.*	*Per cent.*
93	Bread from standard patent flour	0.33	0.06	82
94	Bread from entire-wheat flour	.34	.08	76
95	Bread from graham flour	.34	.14	58

From the results it will be observed that bread from standard patent flour was most completely digested in the acid pepsin solution; bread from entire-wheat flour was less digested; and bread from graham flour was least digested of all the three. These results agree with those obtained in the experiments with men.

In general these results are in accord with the following conclusion concerning the nutritive values of the different grades arrived at by Lawes and Gilbert,[3] who have made extensive experiments with wheat:

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[1] U. S. Dept. Agr., Office of Experiment Stations Bul. 85, p. 42.

[2] U. S. Dept. Agr., Office of Experiment Stations Bul. 43, p. 20.

[3] On Some Points in the Composition of the Wheat Grain of the Product in the Mill and Bread. Reprint. London, Spottiswoode & Co., 1873, p. 33.

The higher percentage of nitrogen in bran than in fine flour has frequently led to the recommendation of the coarser breads as more nutritious than the finer. We have already seen that the more branny portions of the grain also contain a much larger percentage of mineral matter. And, further, it is in the bran that the largest proportion of fatty matter—the nonnitrogenous substance of highest respiratory capacity which the wheat contains—is found. It is, however, we think, very questionable whether upon such data alone a valid opinion can be formed of the comparative values of bread made from the finer or coarser flours ground from one and the same grain. Again, it is an indisputable fact that branny particles when admitted into the flour in the degree of imperfect division in which our ordinary milling processes leave them very considerably increase the peristaltic action, and hence the alimentary canal is cleared much more rapidly of its contents. It is also well known that the poorer classes almost invariably prefer the whiter bread, and among some of those who work the hardest and who consequently soonest appreciate a difference in nutritive quality (navvies, for example) it is distinctly stated that their preference for the whiter bread is founded on the fact that the browner passes through them too rapidly; consequently, before their systems have extracted from it as much nutritious matter as it ought to yield them. * * * In fact, all experience tends to show that the state as well as the chemical composition of our food must be considered; in other words, that the digestibility and aptitude for assimilation are not less important qualities than its ultimate composition.

But to suppose that whole-wheat meal as ordinarily prepared is, as has generally been assumed, weight for weight more nutritious than ordinary bread flour is an utter fallacy founded on theoretical text-book dicta, not only entirely unsupported by experience but inconsistent with it. In fact, it is just the poorer fed and the harder working that should have the ordinary flour bread rather than the whole-meal bread as hitherto prepared, and it is the overfed and the sedentary that should have such whole-meal bread. Lastly, if the whole grain were finely ground it is by no means certain that the percentage of really nutritive nitrogenous matters would be higher than in ordinary bread flour, and it is quite a question whether the excess of earthy phosphates would not then be injurious.

DIGESTIBILITY OF LIBERAL AND RESTRICTED RATIONS.

Thirteen digestion experiments were carried on with young men in normal health, who were given under uniform conditions a ration in liberal and in restricted amounts, the object being to learn whether the food undergoes as complete and perfect digestion when a large amount is consumed as it does when smaller quantities of the same materials are eaten; or, in other words, whether the quantity of food consumed is a factor which affects digestibility. In nine of these experiments the ration consisted of bread and milk and in four of oatmeal and milk. These two food combinations were selected because the coefficient of digestibility of the former is high, as already shown by experiments reported in this bulletin (p. 33), while that of the latter was believed to be lower.[1] The bread and milk was fed in the following ways: (1) A very liberal ration, called a full ration; (2) a two-thirds ration (two-thirds of the full ration), and (3) a half ration (one-half of the full ration). The oatmeal and milk were fed in two ways—(1) a full ration and (2) a half ration.

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[1] Unpublished results obtained by the author.

These experiments were made as before. The digestibility of the bread alone, and the oatmeal alone, was calculated from the results obtained for the total diet by assuming factors for the digestibility of the milk, as already explained.

The bread used was made of flour, yeast, water, and a little salt, all the flour being from the same lot. As pointed out previously,[1] the amount of ether extract obtained when baked bread is analyzed is materially less than the quantity in the flour from which the bread is made. Since the bread was all made from the same flour and in the same manner, it seems reasonable to suppose that the only important difference between any two lots of bread was in the moisture content. Therefore, to lessen the analytical work, the moisture content of each loaf was determined, and a composite sample for analysis was made, which contained a proportionate amount of dry matter from each loaf. A composite sample was also made of all the milk used. This was preserved in good condition for analysis by means of potassium bichromate.

In the experiments with oatmeal, each meal was prepared separately for each subject. A weighed quantity of ordinary rolled oats, obtained in bulk, was placed in a porcelain beaker, and a small amount of salt and a little water added and thoroughly stirred; a sufficient amount of warm water to make mush was then added, and the whole cooked over boiling water for four hours. The amounts of nutrients consumed by each subject were calculated from the amount and composition of the original rolled oats that each one ate. This was found to be more accurate than analyzing the cooked oatmeal, which involved considerable difficulty in sampling. No material loss occurs by volatilization of the nutrients of the oatmeal during cooking.

The subjects were five young men, designated in the tests with bread and milk as Nos. 1, 2, and 3, and in the oatmeal and milk tests, Nos. 4 and 5. They were all employed upon the experiment station farm with the exception of No. 1, who was a university student. Subject No. 2 was engaged in light work, counting and sorting seeds. Subjects Nos. 3 and 4 were employed at ordinary farm labor which was moderately severe, while subject No. 5 was employed at labor of the same character but a little more severe. The men had all been students in the Minnesota School of Agriculture, were interested in these digestion experiments, and fully appreciated the requirements for the success of such work.

The composition of all the foods, feces, and urine of these experiments will be found with those of preceding experiments in Tables 6, 7, and 8, respectively, on pages 18 and 19. The following tables (26 to 38, inclusive) give the statistics of the several experiments.

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[1] U. S. Dept. Agr., Office of Experiment Stations Buls. 35, p. 16; 52, p. 47; 67, pp. 32, 46, and p. 16 of this bulletin.

Table 39 summarizes the results for the digestibility of the ration as a whole, and Table 40 the calculated digestibility of the cereal portion of the diet.

DIGESTION EXPERIMENT NO 173.

Kind of food.—"Full ration" of milk and bread made from standard patent flour.

Subject.—Student No. 1. Twenty-three years old.

Weight.—At beginning of experiment, 152 pounds; at close of experiment, 154 pounds.

Duration.—Two days, with six meals, beginning with breakfast, April 2, 1900.

TABLE 26.—*Results of digestion experiment No. 173.*

Sample No.		Weight of material.	Protein (N×6.25).	Fat.	Carbohydrates.	Ash.	Heat of combustion.
	Food consumed:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
103	Bread	1,891.0	157.9	2.7	993.9	8.5	4,914
102	Milk	4,950.0	149.5	206.4	233.6	39.6	3,772
	Total		307.4	209.1	1,227.5	48.1	8,686
107	Feces (water-free)	78.7	27.2	14.6	18.9	18.0	405
	Estimated feces from food other than bread		4.5		4.7		
	Estimated feces from bread		22.7		14.2		
	Total amount digested		280.2	194.5	1,208.6	30.1	8,281
	Estimated digestible nutrients in bread		135.2		979.7		
	Coefficients of digestibility of total food		*Per ct.* 91.2	*Per ct.* 93.0	*Per ct.* 98.5	*Per ct.* 62.6	*Per ct.* 95.3
	Estimated coefficients of digestibility of bread		85.6		98.6		*a* 96.1
	Proportion of energy actually available to body:						
	In total food						91.3
	In bread alone						*a* 92.6

a Calculated according to assumption that 90 per cent of the fat in the bread is digestible.

During this experiment the subject eliminated 2,763 grams urine, containing 1.53 per cent, or 42.3 grams, nitrogen. The average nitrogen balance per day was therefore as follows: Income in food, 24.6 grams; outgo in urine, 21.2 grams, and in feces, 2.2 grams: implying a gain of 1.2 grams nitrogen, corresponding to 7.5 grams protein. The total heat of combustion of the urine as determined was 365 calories.

DIGESTION EXPERIMENT NO. 174.

Kind of food.—"Full ration" of milk and bread made from standard patent flour.

Subject.—Man No. 2. Twenty-two years old. Employed at office work during five hours of the day, and at average farm labor for the remainder of the time.

Weight.—At the beginning of the experiment, 149 pounds; at the close of the experiment, 152 pounds.

Duration.—Two days, with six meals, beginning with breakfast, April 2, 1900.

TABLE 27.—*Results of digestion experiment No. 174.*

Sample No.		Weight of material.	Protein (N×6.25).	Fat.	Carbohydrates.	Ash.	Heat of combustion.
	Food consumed:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
103	Bread	1,500.0	125.3	2.1	788.4	6.7	3,898
102	Milk	6,150.0	185.7	256.5	290.3	49.2	4,686
	Total	....	311.0	258.6	1,078.7	55.9	8,584
108	Feces (water-free)	74.0	21.0	9.4	31.5	12.2	346
	Estimated feces from food other than bread	....	5.6	....	5.8	....	....
	Estimated feces from bread	....	15.4	....	25.7	....	....
	Total amount digested	....	290.0	249.2	1,047.2	43.7	8,238
	Estimated digestible nutrients in bread	....	109.9	....	762.7	....	....
	Coefficients of digestibility of total food	....	*Per ct.* 93.3	*Per ct.* 96.4	*Per ct.* 97.1	*Per ct.* 78.2	*Per ct.* 96.0
	Estimated coefficients of digestibility of bread	....	87.7	....	96.7	....	*a* 94.9
	Proportion of energy actually available to body:						
	In total food	....	....	....	....	....	91.8
	In bread alone	....	....	....	....	....	*a* 91.4

a Calculated according to the assumption that 90 per cent of the fat in the bread is digestible.

During this experiment the subject eliminated 3,463 grams urine, containing 0.82 per cent, or 28.4 grams, nitrogen. The average nitrogen balance per day was therefore as follows: Income in food, 24.9 grams; outgo in urine, 14.2 grams, and in feces, 1.7 grams; implying a gain of 9 grams nitrogen, corresponding to 56.2 grams protein. The total heat of combustion of the urine as determined was 332 calories.

DIGESTION EXPERIMENT NO. 175.

Kind of food.—"Full ration" of milk and bread made from standard patent flour.

Subject.—Man No. 3. Twenty-one years of age. Employed at farm labor for ten hours a day.

Weight.—At beginning of experiment, 161 pounds; at close of experiment, 160 pounds.

Duration.—Two days, with six meals, beginning with breakfast April 2, 1900.

Table 28.—*Results of digestion experiment No. 175.*

Sample No.		Total organic matter.	Protein (N×6.25).	Fat.	Carbohydrates.	Ash.	Heat of combustion.
	Food consumed:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
103	Bread	1,175.3	159.6	2.7	1,004.4	8.6	4,966
102	Milk	762.6	181.2	250.2	283.2	48.0	4,572
	Total	1,937.9	340.8	252.9	1,287.6	56.6	9,538
109	Feces (water-free)	85.0	21.1	15.6	35.5	12.8	455
	Estimated feces from food other than bread	....	5.4	....	5.7	....	....
	Estimated feces from bread	....	15.7	....	29.8	....	....
	Total amount digested	1,852.9	319.7	237.3	1,252.1	43.8	9,083
	Estimated digestible nutrients in bread	....	143.9	....	974.6	....	....
	Coefficients of digestibility of total food	*Per ct.* 95.6	*Per ct.* 93.8	*Per ct.* 93.8	*Per ct.* 97.3	*Per ct.* 77.4	*Per ct.* 95.2
	Estimated coefficients of digestibility of bread	....	90.2	....	97.0	....	*a* 95.6
	Proportion of energy actually available to body:						
	In total food	....	....	....	....	....	91.0
	In bread alone	....	....	....	....	....	*a* 92.0

a Calculated according to the assumption that 90 per cent of the fat in the bread is digestible.

During this experiment the subject eliminated 3,554 grams urine, containing 1.19 per cent, or 42.3 grams, nitrogen. The average nitrogen balance per day was therefore as follows: Income in food, 27.3 grams; outgo in urine, 21.2 grams, and in feces, 1.7 grams; implying a gain of 4.4 grams nitrogen, corresponding to 27.5 grams protein. The total heat of combustion of the urine as determined was 469 calories.

DIGESTION EXPERIMENT NO. 176.

Kind of food.—"Full ration" of milk and oatmeal.

Subject.—Man No. 4. Twenty-four years of age. Employed at average farm labor.

Weight.—At beginning of experiment, 204 pounds; at close of experiment, 204 pounds.

Duration.—Two days, with six meals, beginning with breakfast, April 2, 1900.

Table 29.—*Results of digestion experiment No. 176.*

Sample No.		Weight of material.	Protein (N×6.25).	Fat.	Carbohydrates.	Ash.	Heat of combustion.
	Food consumed:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
101	Oatmeal	975.0	143.2	167.9	661.9	17.6	4,446
102	Milk	4,100.0	123.8	171.0	193.5	32.8	3,124
	Total	....	267.0	238.9	[illegible]	50.4	7,570
113	Feces (water-free)	148.6	43.4	38.2	[illegible]	26.1	780
	Estimated feces from food other than oatmeal	....	18.6	17.1	[illegible]	....	281
	Estimated feces from oatmeal	....	24.8	[illegible]	[illegible]	....	499
	Total amount digested	....	223.6	200.7	[illegible]	[illegible]	6,790
	Estimated digestible nutrients in oatmeal	....	118.4	46.8	[illegible]	[illegible]	3,947

TABLE 29.—*Results of digestion experiment No. 176*—Continued.

Sample No.		Weight of material.	Protein (N×6.25).	Fat.	Carbohydrates.	Ash.	Heat of combustion.
	Coefficients of digestibility of total food		*Per ct.* 83.7	*Per ct.* 84.0	*Per ct.* 95.2	*Per ct.* 48.2	*Per ct.* 89.7
	Estimated coefficients of digestibility of oatmeal		82.7	68.9	94.4		88.8
	Proportion of energy actually available to body:						
	In total food						86.0
	In oatmeal alone						85.5

During this experiment the subject eliminated 4,375 grams urine. containing 0.84 per cent, or 36.7 grams, nitrogen. The average nitrogen balance per day was therefore as follows: Income in food, 21.4 grams; outgo in urine, 18.4 grams, and in feces, 3.5 grams; implying a loss of 0.5 gram nitrogen, corresponding to 3.1 grams protein. The total heat of combustion of the urine as determined was 363 calories.

DIGESTION EXPERIMENT NO. 177.

Kind of food.—"Full ration" of milk and oatmeal.

Subject.—Man No. 5. Twenty-seven years old. Employed at office work and general work which would be classed as average manual labor.

Weight.—At beginning of experiment, 158½ pounds; at close of experiment, 159 pounds.

Duration.—Two days, with six meals, beginning with breakfast, April 2, 1900.

TABLE 30.—*Results of digestion experiment No. 177.*

Sample No.		Weight of material.	Protein (N×6.25).	Fat.	Carbohydrates.	Ash.	Heat of combustion.
	Food consumed:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
101	Oatmeal	950.0	139.6	66.1	645.0	17.1	4,332
102	Milk	3,900.0	117.8	162.6	184.1	31.2	2,972
	Total		257.4	228.7	829.1	48.3	7,304
114	Feces (water-free)	138.5	46.5	36.1	31.7	24.3	718
	Estimated feces from food other than oatmeal		17.7	16.3	3.7		259
	Estimated feces from oatmeal		28.8	19.8	28.0		459
	Total amount digested		210.9	192.6	797.4	24.0	6,586
	Estimated digestible nutrients in oatmeal		110.8	46.3	617.0		3,873
	Coefficients of digestibility of total food		*Per ct.* 81.9	*Per ct.* 84.2	*Per ct.* 96.2	*Per ct.* 49.7	*Per ct.* 90.2
	Estimated coefficients of digestibility of oatmeal		79.4	70.1	95.7		89.4
	Proportion of energy actually available to body:						
	In total food						86.6
	In oatmeal alone						86.2

During this experiment the subject eliminated 3,349 grams urine, containing 0.93 per cent, or 31.1 grams, nitrogen. The average nitrogen balance per day was therefore as follows: Income in food, 20.6 grams; outgo in urine, 15.6 grams, and in feces, 3.7 grams; implying a gain of 1.3 grams nitrogen, corresponding to 8.1 grams protein. The total heat of combustion of the urine as determined was 378 calories.

DIGESTION EXPERIMENT NO. 178.

Kind of food.—"Two-thirds ration" of milk and bread made from standard patent flour.

Subject.—Student No. 1. This experiment was performed under conditions similar to those in experiment No. 173.

Weight.—At beginning of experiment, 152¾ pounds; at close of experiment, 151¾ pounds.

Duration.—Two days, with six meals, beginning with breakfast, April 6, 1900.

TABLE 31.—*Results of digestion experiment No. 178.*

Sample No.		Weight of material.	Protein (N×6.25).	Fat.	Carbohydrates.	Ash.	Heat of combustion.
	Food consumed:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
118	Bread	1,339.0	112.5	1.3	717.3	5.8	3,531
129	Milk	3,000.0	88.2	129.9	146.4	25.2	2,265
	Total		200.7	131.2	863.7	31.0	5,796
126	Feces (water-free)	52.1	15.4	7.7	19.2	9.9	257
	Estimated feces from food other than bread		2.6	6.5	2.9		92
	Estimated feces from bread		12.8	1.2	16.3		165
	Total amount digested		185.3	123.5	844.5	21.1	5,539
	Estimated digestible nutrients in bread		99.7	.1	701.0		3,366
	Coefficients of digestibility of total food		*Per ct.* 92.3	*Per ct.* 94.1	*Per ct.* 97.8	*Per ct.* 68.1	*Per ct.* 95.6
	Estimated coefficients of digestibility of bread		88.6		97.7		95.3
	Proportion of energy actually available to body:						
	In total food						91.6
	In bread alone						91.8

During this experiment the subject eliminated 1,949 grams urine, containing 1.57 per cent, or 30.6 grams, nitrogen. The average nitrogen balance per day was therefore as follows: Income in food, 16 grams; outgo in urine, 15.3 grams, and in feces, 1.3 grams; implying a loss of 0.6 gram nitrogen, corresponding to 3.8 grams protein. The total heat of combustion of the urine as determined was 255 calories.

DIGESTION EXPERIMENT NO. 179.

Kind of food.—"Two-thirds ration" of milk and bread made from standard patent flour.

Subject.—Man No. 2. This experiment was performed under conditions similar to those in experiment No. 174.

Weight.—At beginning of experiment, 153 pounds; at close of experiment, 154 pounds.

Duration.—Two days, with six meals, beginning with breakfast, April 6, 1900.

TABLE 32.—*Results of digestion experiment No. 179.*

Sample No.		Weight of material.	Protein (N×6.25).	Fat.	Carbohydrates.	Ash.	Heat of combustion.
	Food consumed:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
118	Bread	1,025.0	86.1	1.0	549.1	4.4	2,703
129	Milk	3,600.0	105.8	155.9	175.7	30.2	2,718
	Total	....	191.9	156.9	724.8	34.6	5,421
127	Feces (water-free)	53.6	15.7	7.2	18.8	12.0	285
	Estimated feces from food other than bread	....	3.2	....	3.5	....	....
	Estimated feces from bread	....	12.5	....	15.3	....	....
	Total amount digested	....	176.2	149.7	706.0	22.6	5,136
	Estimated digestible nutrients in bread	....	73.6	....	533.8	....	....
	Coefficients of digestibility of total food	....	*Per ct.* 91.8	*Per ct.* 95.4	*Per ct.* 97.4	*Per ct.* 65.3	*Per ct.* 94.8
	Estimated coefficients of digestibility of bread	....	85.5	....	97.2	....	*a* 94.9
	Proportion of energy actually available to body:						
	In total food	....	....	....	....	....	90.7
	In bread alone	....	....	....	....	....	*a* 91.5

a Calculated according to the assumption that 90 per cent of the fat in the bread is digestible.

During this experiment the subject eliminated 2,414 grams urine, containing 0.81 per cent, or 19.6 grams, nitrogen. The average nitrogen balance per day was therefore as follows: Income in food 15.3 grams; outgo in urine, 9.8 grams, and in feces, 1.2 grams; implying a gain of 4.3 grams nitrogen, corresponding to 26.9 grams protein. The total heat of combustion of the urine as determined was 217 calories.

DIGESTION EXPERIMENT NO. 180.

Kind of food.—"Two-thirds ration" of milk and bread made from standard patent flour.

Subject.—Man No. 3. This experiment was performed under conditions similar to those in experiment No. 175.

Weight.—At beginning of experiment, 160 pounds; at close of experiment, 159½ pounds.

Duration.—Two days, with six meals, beginning with breakfast, April 6, 1900.

TABLE 33.—*Results of digestion experiment No. 180.*

Sample No.		Weight of material.	Protein (N×6.25).	Fat.	Carbohydrates.	Ash.	Heat of combustion.
	Food consumed:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
118	Bread	1,350.0	113.4	1.4	723.2	5.8	3,560
129	Milk	3,600.0	105.8	155.9	175.7	30.2	2,718
	Total		219.2	157.3	898.9	36.0	6,278
128	Feces (water-free)	52.7	17.0	7.8	18.3	9.6	279
	Estimated feces from food other than bread		3.2		3.5		
	Estimated feces from bread		13.8		14.8		
	Total amount digested		202.2	149.5	880.6	26.4	5,999
	Estimated digestible nutrients in bread		99.6		708.4		
	Coefficients of digestibility of total food		*Per ct.* 92.2	*Per ct.* 95.0	*Per ct.* 98.0	*Per ct.* 73.3	*Per ct.* 95.6
	Estimated coefficients of digestibility of bread		87.8		98.0		*a*96.0
	Proportion of energy actually available to body:						
	In total food						91.5
	In bread alone						*a*92.5

a Calculated according to the assumption that 90 per cent of the fat in the bread is digestible.

During this experiment the subject eliminated 1,960 grams urine, containing 1.5 per cent, or 29.4 grams, nitrogen. The average nitrogen balance per day was therefore as follows: Income in food, 17.5 grams; outgo in urine, 14.7 grams, and in feces, 1.4 grams; implying a gain of 1.4 grams nitrogen, corresponding to 8.8 grams protein. The total heat of combustion of the urine as determined was 274 calories.

DIGESTION EXPERIMENT NO. 181.

Kind of food.—"One-half ration" of milk and oatmeal.

Subject.—Man No. 4. This experiment was performed under conditions similar to those in experiment No. 176.

Weight.—At the beginning of experiment, 204 pounds; at close of experiment, 202 pounds.

Duration.—Two days, with six meals, beginning with breakfast, April 6, 1900.

TABLE 34.—*Results of digestion experiment No. 181.*

Sample No.		Weight of material.	Protein (N×6.25).	Fat.	Carbohydrates.	Ash.	Heat of combustion.
	Food consumed:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
101	Oatmeal	675.0	99.2	47.0	458.2	12.1	3,078
115	Milk	3,310.0	90.0	123.1	154.9	28.1	2,224
	Total		189.2	170.1	613.1	40.2	5,302
121	Feces (water-free)	63.0	17.5	16.2	15.9	13.4	326
	Estimated feces from food other than oatmeal		13.5	12.3	3.1		209
	Estimated feces from oatmeal		4.0	3.9	12.8		117
	Total amount digested		171.7	153.9	597.2	26.8	4,976
	Estimated digestible nutrients in oatmeal		95.2	43.1	445.5		2,961

TABLE 34.—*Results of digestion experiment No. 181*—Continued.

Sample No.		Weight of material.	Protein (N×6.25).	Fat.	Carbohydrates.	Ash.	Heat of combustion.
	Coefficients of digestibility of total food		*Per ct.* 90.8	*Per ct.* 90.5	*Per ct.* 97.4	*Per ct.* 66.7	*Per ct.* 93.9
	Estimated coefficients of digestibility of oatmeal		96.0	91.7	97.2		96.2
	Proportion of energy actually available to body:						
	In total food						89.8
	In oatmeal alone						92.3

During this experiment the subject eliminated 2,122 grams urine, containing 0.96 per cent, or 20.4 grams, nitrogen. The average nitrogen balance per day was therefore as follows: Income in food, 15.2 grams; outgo in urine, 10.2 grams, and in feces 1.4 grams; implying a gain of 3.6 grams nitrogen, corresponding to 22.5 grams protein. The total heat of combustion of the urine as determined was 178 calories.

DIGESTION EXPERIMENT NO. 182.

Kind of food.—"One-half ration" of milk and oatmeal.

Subject.—Man No. 5. This experiment was performed under conditions similar to those of experiment No. 177.

Weight.—At beginning of experiment, 158 pounds; at close of experiment, 157 pounds.

Duration.—Two days, with six meals, beginning with breakfast, April 6, 1900.

TABLE 35.—*Results of digestion experiment No. 182.*

Sample No.		Weight of material.	Protein (N×6.25).	Fat.	Carbohydrates.	Ash.	Heat of combustion.
	Food consumed:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
101	Oatmeal	475.0	69.8	33.1	322.5	8.6	2,166
117	Milk	2,750.0	85.3	107.8	127.9	22.6	2,002
	Total		155.1	140.9	450.4	31.2	4,168
122	Feces (water-free)	56.7	16.6	12.7	16.8	10.7	291
	Estimated feces from food other than oatmeal		12.8	10.8	2.6		188
	Estimated feces from oatmeal		3.8	1.9	14.2		103
	Total amount digested		138.5	128.2	433.6	20.5	3,877
	Estimated digestible nutrients in oatmeal		66.0	31.2	308.3		2,063
	Coefficients of digestibility of total food		*Per ct.* 89.3	*Per ct.* 91.0	*Per ct.* 96.3	*Per ct.* 65.7	*Per ct.* 93.0
	Estimated coefficients of digestibility of oatmeal		94.6	94.3	95.6		95.3
	Proportion of energy actually available to body:						
	In total food						88.9
	In oatmeal alone						91.4

During this experiment the subject eliminated 1,501 grams urine, containing 1.54 per cent, or 23.1 grams, nitrogen. The average nitrogen balance per day was, therefore, as follows: Income in food, 12.4 grams; outgo in urine, 11.6 grams, and in feces 1.4 grams; implying a loss of 0.6 gram nitrogen, corresponding to 3.8 grams protein. The total heat of combustion of the urine as determined was 170 calories.

DIGESTION EXPERIMENT NO. 186.

Kind of food.—"Half ration" of milk and bread made from standard patent flour.

Subject.—Student No. 1. This experiment was performed under conditions similar to those of experiments Nos. 173 and 178.

Weight.—At beginning of experiment, 154 pounds; at close of experiment, 149 pounds.

Duration.—Two days, with six meals, beginning with breakfast, April 20, 1900.

TABLE 36.—*Results of digestion experiment No. 186.*

Sample No.		Weight of material.	Protein (N × 6.25).	Fat.	Carbohydrates.	Ash.	Heat of combustion.
	Food consumed:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
140	Bread	960.0	81.7	1.0	525.1	4.2	2,583
138	Milk	3,600.0	109.4	152.3	179.6	26.3	2,650
	Total		191.1	153.3	704.7	30.5	5,233
144	Feces (water-free)	37.0	8.8	4.5	14.0	9.8	179
	Estimated feces from food other than bread		3.3		3.6		
	Estimated feces from bread		5.5		10.4		
	Total amount digested		182.3	148.8	690.7	20.7	5,054
	Estimated digestible nutrients in bread		76.2		514.7		
	Coefficients of digestibility of total food		*Per ct.* 95.4	*Per ct.* 97.1	*Per ct.* 98.0	*Per ct.* 67.9	*Per ct.* 96.6
	Estimated coefficients of digestibility of bread		93.3		98.0		*a* 97.0
	Proportion of energy actually available to body:						
	In total food						92.0
	In bread alone						*a* 93.3

a Calculated according to the assumption that 90 per cent of the fat in the bread is digestible.

During this experiment the subject eliminated 2,283 grams urine, containing 1.64 per cent, or 37.4 grams, nitrogen. The average nitrogen balance per day was therefore as follows: Income in food, 15.3 grams; outgo in urine, 18.7 grams, and in feces, 0.7 grams; implying a loss of 4.1 grams nitrogen, corresponding to 25.6 grams protein. The total heat of combustion of the urine as determined was 292 calories.

DIGESTION EXPERIMENT NO. 187.

Kind of food.—"Half ration" of milk and bread made from standard patent flour.

Subject.—Man No. 2. This experiment was performed under conditions similar to those of experiments Nos. 174 and 179.

Weight.—At beginning of experiment, 154 pounds; at close of experiment, 153 pounds.

Duration.—Two days, with six meals, beginning with breakfast, April 20, 1900.

TABLE 37.—*Results of digestion experiment No. 187.*

Sample No.		Weight of material.	Protein (N×6.25).	Fat.	Carbohydrates.	Ash.	Heat of combustion.
	Food consumed:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
140	Bread	750.0	63.8	0.8	410.2	3.3	2,018
139	Milk	3,000.0	88.8	117.3	132.6	21.9	2,181
	Total	....	152.6	118.1	542.8	25.2	4,199
145	Feces (water-free)	32.3	8.4	3.7	11.5	8.7	140
	Estimated feces from food other than bread	....	2.7	....	2.7	....	....
	Estimated feces from bread	....	5.7	....	8.8	....	....
	Total amount digested	....	144.2	114.4	531.3	16.5	4,059
	Estimated digestible nutrients in bread	....	58.1	....	401.4	....	....
	Coefficients of digestibility of total food		*Per ct.* 94.5	*Per ct.* 96.9	*Per ct.* 97.9	*Per ct.* 65.5	*Per ct.* 96.7
	Estimated coefficients of digestibility of bread	....	91.1	....	97.9	....	*a* 96.5
	Proportion of energy actually available to body:						
	In total food	....	....	....	....	....	92.4
	In bread alone	....	....	....	....	....	*a* 92.9

a Calculated according to the assumption that 90 per cent of the fat in the bread is digestible.

During this experiment the subject eliminated 2,029 grams urine, containing 0.94 per cent, or 19.1 grams, nitrogen. The average nitrogen balance per day was therefore as follows: Income in food, 12.2 grams; outgo in urine, 9.6 grams, and in feces, 0.7 grams; implying a gain of 1.9 grams nitrogen, corresponding to 12.8 grams protein. The total heat of combustion of the urine as determined was 193 calories.

DIGESTION EXPERIMENT NO. 188.

Kind of food.—"Half ration" of milk and bread made from standard patent flour.

Subject.—Man No. 3. This experiment was performed under conditions similar to those of experiments Nos. 175 and 180.

Weight.—At beginning of experiment, 158 pounds; at close of experiment, 156 pounds.

Duration.—Two days, with six meals, beginning with breakfast, April 20, 1900.

TABLE 38.—*Results of digestion experiment No. 188.*

Sample No.		Weight of material.	Protein (N×6.25).	Fat.	Carbohydrates.	Ash.	Heat of combustion.
	Food consumed:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
140	Bread	960.0	81.7	1.0	525.1	4.2	2,583
139	Milk	3,000.0	88.8	117.3	132.6	21.9	2,181
	Total		170.5	118.3	657.7	26.1	4,764
146	Feces (water-free)	42.6	9.5	6.2	15.7	11.3	215
	Estimated feces from food other than bread		2.7	5.9	2.7		97
	Estimated feces from bread		6.8	.3	13.0		118
	Total amount digested		161.0	112.1	642.0	14.8	4,549
	Estimated digestible nutrients in bread		74.9	.7	512.1		2,465
	Coefficients of digestibility of total food		*Per ct.* 94.4	*Per ct.* 94.8	*Per ct.* 97.6	*Per ct.* 56.7	*Per ct.* 95.5
	Estimated coefficients of digestibility of bread		91.7	70.0	97.5		95.4
	Proportion of energy actually available to body:						
	In total food						91.3
	In bread alone						91.8

During this experiment the subject eliminated 2.480 grams urine, containing 1.98 per cent. or 49.1 grams, nitrogen. The average nitrogen balance per day was therefore as follows: Income in food, 13.6 grams; outgo in urine, 24.6 grams, and in feces, 0.8 gram; implying a loss of 11.8 grams nitrogen, corresponding to 73.8 grams protein. The total heat of combustion of the urine as determined was 248 calories.

Table 39 gives a summary of the results for the digestibility of the total diet in the thirteen digestion experiments with the full, two-thirds, and half rations.

TABLE 39.—*Summary of digestion experiments Nos. 173–182 and 186–188—Digestibility of nutrients and availability of energy of total food.*

Experiment No.	Subject No.	Kind of food.	Ration.	Protein.	Fat.	Carbohydrates.	Ash.	Energy.
				Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
173	1	Bread and milk	Full	91.2	93.0	98.5	62.6	91.3
178	1	.....do	Two-thirds	92.3	94.1	97.8	68.1	91.6
186	1	.....do	One-half	95.4	97.1	98.0	67.7	92.0
174	2	.....do	Full	93.3	96.4	97.1	78.2	91.8
179	2	.....do	Two-thirds	91.8	95.4	97.4	65.3	90.7
187	2	.....do	One-half	94.5	96.9	97.9	65.5	92.4
175	3	.....do	Full	93.8	93.8	97.3	77.4	91.0
180	3	.....do	Two-thirds	92.2	95.0	98.0	73.3	91.5
188	3	.....do	One-half	94.4	94.8	97.6	56.7	91.3
		Average, 3 subjects	Full	92.8	94.4	97.6	72.7	91.4
		Do.	Two-thirds	92.1	94.7	97.7	68.9	91.2
		Do.	One-half	94.8	96.3	97.8	63.4	91.9
176	4	Oatmeal and milk	Full	83.7	84.0	95.2	48.2	86.0
181	4	.....do	One-half	90.8	90.5	97.4	66.7	89.8
177	5	.....do	Full	81.9	84.2	96.2	49.7	86.6
182	5	.....do	One-half	89.3	91.0	96.3	65.7	88.9
		Average, 2 subjects	Full	82.8	84.1	95.7	49.0	86.3
		Do.	One-half	90.0	90.8	96.9	66.2	89.4

The following table summarizes the digestibility of the bread alone and the oatmeal alone, as computed from the digestibility of the total diet by assuming certain factors for the digestibility of the nutrients in the milk. As previously stated, the results for the digestibility of the fat in the bread in some of the experiments could not be satisfactorily determined and are therefore omitted. For the sake of estimating the available energy in the bread it was assumed that 90 per cent of the fat in the bread was digestible.

TABLE 40.—*Digestibility of nutrients and availability of energy in bread alone and in oatmeal alone.*

Experiment No.	Subject No.	Kind of food.	Ration.	Protein.	Fat.	Carbohydrates.	Energy.
				Per ct.	*Per ct.*	*Per ct.*	*Per ct.*
173	1	Bread	Full	85.6	....	98.6	92.6
178	1	....do	Two-thirds	88.6	....	97.7	91.8
186	1	....do	One-half	93.3	....	98.0	93.3
174	2	....do	Full	87.7	....	96.7	91.4
179	2	....do	Two-thirds	85.5	....	97.2	91.5
187	2	....do	One-half	91.1	....	97.9	92.9
175	3	....do	Full	90.2	....	97.0	92.0
180	3	....do	Two-thirds	87.8	....	98.0	92.5
188	3	....do	One-half	91.7	....	97.5	91.8
		Average, 3 subjects	Full	87.8	....	97.4	92.0
		Do	Two-thirds	87.3	....	97.6	91.9
		Do	One-half	92.0	....	97.8	92.7
176	4	Oatmeal	Full	82.7	68.9	94.4	85.5
181	4	....do	One-half	96.0	91.7	97.2	92.3
177	5	....do	Full	79.4	70.1	95.7	86.2
182	5	....do	One-half	94.6	94.3	95.6	91.4
		Average, 2 subjects	Full	81.0	69.5	95.0	85.8
		Do	One-half	95.3	93.0	96.4	91.9

There is a slight error in the results given in the tables above, because no corrections have been made for biliary and other forms of metabolic nitrogen. It may be that in the smaller amount of feces from the half rations there is proportionally more of such nitrogen than in the larger quantities of feces from the other rations, in which case the error is proportionally greater and would have more effect upon the results from the smaller ration. As no satisfactory means have as yet been devised for determining the amount of metabolic nitrogen in the feces, the influence which it exerts upon the digestion coefficients can be considered only in a general way in the discussion of the results. The following are the chief features brought out by comparison of the results of total food summarized in the table above.

Subject No. 1 digested a larger proportion of both the protein and the fat from the half ration than from the full ration, the difference being approximately 4 per cent for each of these nutrients. The proportion of carbohydrates digested was a little less from the half than from the whole ration. In the case of this man, engaged in study at the university, the digestive tract apparently did more thorough work on the half ration than on the full ration. While the differences in

favor of the half ration are not large, they are, with the exception of the carbohydrates, larger than would be ordinarily considered within the limits of experimental error.

Subject No. 2 also digested a larger proportion of both the protein and the fat from the half ration than from the full ration, the differences, however—1.2 per cent in the case of protein and 0.5 per cent in the case of fat—being less than with subject No. 1.

In the case of subject No. 3, the amount of protein digested from the half ration was 6 per cent, that of the fat 1 per cent, and that of the carbohydrates 0.3 per cent larger than from the full ration.

If the average of the results from the half ration for the three subjects be compared with those from the full ration, there is observed a difference of approximately 2 per cent in favor of the half ration as regards the thoroughness with which both protein and fat were digested, while little difference in the digestibility of the carbohydrates was observed. The results were affected by the individual peculiarities of the different subjects, the work at which each was employed, or some other factor which is not understood.

In the experiments with oatmeal and milk the differences are more pronounced. The amount of protein digested from the half ration was 7.1 per cent larger, and that of fat 6.5 per cent larger, than from the full ration for subject No. 4, while for subject No. 5 the differences were 7.4 per cent protein and 6.8 per cent fat in favor of the half ration. There seems to be a marked uniformity of results in favor of the digestibility of the half ration of oatmeal and milk over the full ration of the same foods.

Comparing the results of the experiments with subjects consuming the two-thirds ration and the full ration, no constant differences in favor of either were observed. With subject No. 1 larger proportions were digested from the two-thirds ration, while with subject No. 2 the full ration was more thoroughly digested. Subject No. 3 digested a larger proportion of protein and a smaller proportion of fat from the full ration. If similar comparisons are made of the computed digestibility of bread alone, the differences are somewhat more noticeable than in the case of the total food, but also indicate that there is no advantage in the two-thirds ration over the full ration in the proportions digested, while the half ration is more thoroughly digestible than the full ration. It will be remembered that in these investigations on the effect of the quantity of food upon the proportions digested, the terms "full," "two-thirds," and "half" rations are used in a comparative sense only. The "full" ration taken as a standard furnished what was considered more than a liberal amount of nutrients, the "two-thirds" ration furnished two-thirds as much nutritive material, and the "half" ration half as much.

It is not the intention, on the basis of these experiments, to convey

the idea that a half ration is preferable to a full ration. The results simply indicate that when food is taken in small amounts it is more thoroughly digested than when taken in large amounts, and that it is possible for the digestive tract to be supplied with such a quantity of food that the highest degree of digestibility is not secured.

EFFECT UPON DIGESTIBILITY OF INCREASING THE PROPORTION OF STARCH IN BREAD.

Three experiments were made to determine the effect upon digestibility of increasing the proportion of starch in bread. Wheat starch was used. It was obtained by the following method from the same lot of flour as that used for the bread: A portion of flour (sample No. 137) was mixed with water to a stiff dough, which was allowed to stand for half an hour. The dough was then put into a linen bag and washed with water, the starch being removed in the water and the gluten remaining in the bag. The starch was allowed to settle, was washed a second time, and then dried and pulverized.

A mixture of flour and starch was prepared containing approximately 20 per cent starch and 80 per cent flour, and bread was made from it by the usual methods. The addition of the 20 per cent of wheat starch to the flour produced a mixture very similar in chemical composition to many flours of low protein content found on the market. The only material difference in the composition of most wheat flours is in the ratio of protein to carbohydrates, a high or low protein content being accompanied by a correspondingly low or high carbohydrate content. The flour with 20 per cent additional starch, therefore, to all intents and purposes, is simply a flour with low protein content. It is believed that the results of the following experiments with starch bread, when compared with those of preceding experiments with ordinary bread, may be fairly assumed to show the relative digestibility of bread made from flours with low and high percentages of protein.

The experiments with starch bread and milk (Nos. 183–185) were made with the same subjects and under the same conditions as the experiments with a "two-thirds ration" of ordinary bread and milk (Nos. 179–181), which have been previously discussed. It was considered more satisfactory to make the comparison with a ration of average amount rather than with the full or the half ration.

The composition of the flour (sample No. 147), of the wheat starch (sample No. 100), of the starch-flour bread (sample No. 131), and of the bread from the same flour without the extra starch are all given in Table 5. The details of the three experiments are given in the following tables (Nos. 41 to 43), which show the digestibility of the total diet and also of the bread alone, as calculated by assuming certain factors for the digestibility of milk, as previously explained.

DIGESTION EXPERIMENT NO. 183.

Kind of food.—"Two-thirds ration" of milk and bread made from flour with 20 per cent additional starch.

Subject.—Student No. 1. This experiment was performed under conditions similar to those of experiment No. 178.

Weight.—At beginning of experiment, 154 pounds; at close of experiment, 153 pounds.

Duration.—Two days with six meals, beginning with breakfast, April 12, 1900.

TABLE 41.—*Results of digestion experiment No. 183.*

Sample No.		Weight of material.	Protein (N×6.25).	Fat.	Carbohydrates.	Ash.	Heat of combustion.
	Food consumed:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
131	Bread	1,350.0	94.0	1.5	779.4	7.5	3,662
130	Milk	3,000.0	90.6	118.5	147.6	22.5	2,202
	Total	....	184.6	120.0	927.0	30.0	5,864
132	Feces (water-free)	59.0	15.3	8.9	18.6	16.3	285
	Estimated feces from food other than bread	....	2.7	....	3.0	....	....
	Estimated feces from bread	....	12.6	....	15.6	....	....
	Total amount digested	....	169.3	111.1	908.4	13.7	5,579
	Estimated digestible nutrients in bread	....	81.4	....	763.8	....	....
	Coefficients of digestibility of total food	....	*Per ct.* 91.7	*Per ct.* 92.6	*Per ct.* 98.0	*Per ct.* 45.7	*Per ct.* 95.2
	Estimated coefficients of digestibility of bread	....	86.6	....	98.0	....	*a* 96.2
	Proportion of energy actually available to body:						
	In total food	....	....	....	....	....	91.5
	In bread alone	....	....	....	....	....	*a* 93.4

a Calculated according to the assumption that 90 per cent of the fat in the bread is digestible.

During this experiment the subject eliminated 2,221 grams urine, containing 1.55 per cent, or 34.4 grams, nitrogen. The average nitrogen balance per day was therefore as follows: Income in food, 14.8 grams; outgo in urine, 17.2 grams, and in feces, 1.2 grams, implying a loss of 3.6 grams nitrogen, corresponding to 22.4 grams protein. The total heat of combustion of the urine as determined was 271 calories.

DIGESTION EXPERIMENT NO. 184.

Kind of food.—"Two-thirds ration" of milk and bread made from flour with 20 per cent additional starch.

Subject.—Man No. 2. This experiment was performed under conditions similar to those of experiment No. 179.

Weight.—At beginning of experiment, 155 pounds; at close of experiment, 155½ pounds.

Duration.—Two days with six meals, beginning with breakfast, April 12, 1900.

TABLE 42.—*Results of digestion experiment No. 184.*

Sample No.		Weight of material.	Protein (N×6.25).	Fat.	Carbohydrates.	Ash.	Heat of combustion.
	Food consumed:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
131	Bread	1,050.0	73.1	1.2	606.2	5.8	2,848
130	Milk	3,600.0	108.7	142.2	177.1	27.0	2,642
	Total	....	181.8	143.4	783.3	32.8	5,490
134	Feces (water-free)	52.2	16.2	6.0	16.2	13.9	251
	Estimated feces from food other than bread	....	3.3	....	3.5	....	....
	Estimated feces from bread	....	12.9	....	12.7	....	....
	Total amount digested	....	165.6	137.4	767.1	18.9	5,239
	Estimated digestible nutrients in bread	....	60.2	....	593.5	....	....
	Coefficients of digestibility of total food	....	*Per ct.* 91.1	*Per ct.* 95.8	*Per ct.* 97.9	*Per ct.* 57.6	*Per ct.* 95.4
	Estimated coefficients of digestibility of bread	....	82.4	....	97.9	....	*a* 95.5
	Proportion of energy actually available to body:						
	In total food	....	....	....	....	....	91.7
	In bread alone	....	....	....	....	....	*a* 92.8

a Calculated according to the assumption that 90 per cent of the fat in the bread is digestible.

During this experiment the subject eliminated 2,060 grams urine, containing 0.83 per cent, or 17.1 grams, nitrogen. The average nitrogen balance per day was therefore as follows: Income in food, 14.6 grams; outgo in urine, 8.6 grams, and in feces, 1.3 grams; implying a gain of 4.7 grams nitrogen, corresponding to 29.5 grams protein. The total heat of combustion of the urine as determined was 175 calories.

DIGESTION EXPERIMENT NO. 185.

Kind of food.—"Two-thirds ration" of milk and bread made from flour with 20 per cent additional starch.

Subject.—Man No. 3. This experiment was performed under conditions similar to those of experiment No. 180.

Weight.—At beginning of experiment, 160 pounds; at close of experiment, 160 pounds.

Duration.—Two days with six meals, beginning with breakfast, April 12, 1900.

TABLE 43.—*Results of digestion experiment No. 185.*

Sample No.		Weight of material.	Protein (N×6.25).	Fat.	Carbohydrates.	Ash.	Heat of combustion.
	Food consumed:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
131	Bread	1,350.0	94.0	1.5	779.4	7.5	3,662
130	Milk	3,600.0	108.7	142.2	177.1	27.0	2,642
	Total		202.7	143.7	956.5	34.5	6,304
133	Feces (water-free)	62.3	18.9	11.5	20.8	11.1	323
	Estimated feces from food other than bread		3.3		3.5		
	Estimated feces from bread		15.6		17.3		
	Total amount digested		183.8	132.2	935.7	23.4	5,981
	Estimated digestible nutrients in bread		78.4		762.1		
	Coefficients of digestibility of total food		*Per ct.* 90.7	*Per ct.* 92.0	*Per ct.* 97.8	*Per ct.* 67.8	*Per ct.* 94.9
	Estimated coefficients of digestibility of bread		83.4		97.8		*a* 95.5
	Proportion of energy actually available to body:						
	In total food						91.2
	In bread alone						*a* 92.9

a Calculated according to the assumption that 90 per cent of the fat in the bread is digestible.

During this experiment the subject eliminated 1,574 grams urine, containing 1.64 per cent, or 25.8 grams, nitrogen. The average nitrogen balance per day was therefore as follows: Income in food, 16.2 grams; outgo in urine, 12.9 grams, and in feces, 1.5 grams; implying a gain of 1.8 grams nitrogen, corresponding to 11.3 grams protein. The total heat of combustion of the urine as determined was 217 calories.

The following table summarizes the results for the digestibility of total food in the three experiments with a ration of starch bread and milk. For the sake of comparison there are also given in the table the results of three experiments with the same subjects on a diet of ordinary bread and milk.

TABLE 44.—*Summary of digestion experiments Nos. 183–185—Digestibility of nutrients and availability of energy of total food in starch bread and milk compared with ordinary bread and milk.*

Experiment No.	Subject No.	Kind of food.	Protein.	Fat.	Carbohydrates.	Ash.	Energy.
			Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
178	1	Ordinary bread and milk	92.3	94.1	97.8	68.1	91.6
183	1	Starch bread and milk	91.7	92.6	98.0	45.7	91.5
179	2	Ordinary bread and milk	91.8	95.4	97.4	65.3	90.7
184	2	Starch bread and milk	91.1	95.8	97.9	57.6	91.7
180	3	Ordinary bread and milk	92.2	95.0	98.0	73.3	91.5
185	3	Starch bread and milk	90.7	92.0	97.8	67.8	91.2
		Ordinary bread and milk, average 3 subjects	92.1	94.8	97.7	68.9	91.3
		Starch bread and milk, average 3 subjects	91.2	93.5	97.6	57.1	91.5

The amount of milk consumed with the starch bread was practically the same as in the experiments with the ordinary bread. Hence, it

would seem fair to assume that any difference in results might be ascribed to actual differences in the digestibility of the two sorts of bread or, what is really the same thing, of flour of low and high protein content.

Subject No. 1 digested the protein of the ordinary-bread ration somewhat more completely than the protein of the starch-bread ration, the difference, however, being only 0.6 per cent. With subject No. 2 the difference was also small, being 0.7 per cent, while with subject No. 3 it is somewhat larger, being 1.5 per cent. Taking the average for the three subjects, the coefficient of digestibility of the protein of the ordinary bread was found to be 0.9 per cent greater than that of the starch bread.

The calculated digestibility of the two sorts of bread alone is shown in the following table:

TABLE 45.—*Digestibility of nutrients and availability of energy of bread alone, in starch bread compared with ordinary bread.*

Experiment No.	Subject No.	Kind of food.	Protein.	Carbohydrates.	Energy.
			Per cent.	*Per cent.*	*Per cent.*
178	1	Ordinary bread	88.6	97.7	91.8
183	1	Starch bread	86.6	98.0	93.4
179	2	Ordinary bread	85.5	97.2	91.5
184	2	Starch bread	82.4	97.9	92.8
180	3	Ordinary bread	87.8	98.0	92.5
185	3	Starch bread	83.4	97.8	92.9
		Ordinary bread, average 3	87.3	97.6	91.9
		Starch bread, average 3	84.1	97.9	93.0

The same factors were employed for calculating the digestibility of each kind of bread alone, and it is believed that the results may fairly be compared with one another. It appears that subject No. 1 digested 2 per cent, subject No. 2 digested 3 per cent, and subject No. 3 digested 4 per cent more protein from the ordinary bread than from the starch bread.

Thus, whether the comparison is made on the basis of the total diet or the bread alone, the difference in digestibility appears to be in favor of the bread with the larger proportion of protein. A study of digestion coefficients of food in general suggests that the difference in favor of the digestibility of the protein in the bread with the higher protein content is due to the character of the ration and not to individual peculiarities of the subject or some similar cause. Potatoes, for example, have shown the following digestibility:[1] Protein 71.9 per cent and carbohydrates 93 per cent. Potatoes contain a low percentage of protein and a high percentage of carbohydrates, the ratio of protein to starch being approximately 1 to 10; that is, the protein is diluted with a large amount of starch. In the original flour

[1] U. S. Dept. Agr., Office of Experiment Stations Bul. 43, p. 23.

used in these digestion experiments the ratio of protein to starch was 1 to 5.8, while in the bread made from the same flour as diluted with about 20 per cent of starch the ratio was 1 to 8.3. The widening of the ratio of protein to starch in the bread lowered the coefficient of digestibility of the protein about 1 or 2 per cent.

In a former report[1] is given the digestibility of bread made from patent flour as compared with that made from clear or bakers' grade flour, the two kinds of bread being eaten with eggs and butter. The clear or bakers' grade of flour contained 3.04 per cent more protein than the patent roller-process flour. The protein content of the ration containing bread from the former was thus increased about as much as it was decreased in the experiments with starch bread, herewith reported. A difference of only 0.5 per cent was observed in favor of the digestibility of the clear grade flour, with the higher percentage of protein.

The two series of experiments indicate that a proportionally small amount of protein is less thoroughly digested than a proportionally large amount. In the results of both series of experiments the differences are too small and the proportions of metabolic products in the feces are too uncertain to warrant definite conclusions; but the results are suggestive, and are a further indication that the coefficient of digestibility of a nutrient in an article of diet is not constant, but may be affected by the proportion in which the nutrient is combined with others.

BREAD-MAKING EXPERIMENTS.

Several experiments were made to study the effect upon the quality of the bread of modifications in the process of bread making, such as increasing or diminishing the proportion of wheat starch in the flour; raising or lowering the temperature of the flour; prolonged heating of the flour at different temperatures, and blending flours of different grades.

QUALITY OF BREAD AS AFFECTED BY INCREASING OR DIMINISHING THE PROPORTION OF STARCH IN THE FLOUR.

In the comparison of bread made from mixtures of flour and wheat starch and bread made from normal flour, the starch was prepared from flour in the manner described on page 51. The flour used (sample No. 149, Table 6) contained 12 per cent protein, and yielded a hard yellowish gluten containing 62.8 per cent of gliadin and 37.2 per cent of glutenin. Two mixtures of wheat starch and normal flour were used, one containing 10 and the other 20 per cent of the starch. These mixtures are for convenience called "starch flours." In making the

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[1] U. S. Dept. Agr., Office of Experiment Stations Bul. 67, p. 35.

A *B* *C*

A, Bread from standard flour; *B*, bread from flour with 10 per cent wheat starch added; *C*, bread from flour with 20 per cent wheat starch added.

A *B* *C*

A, Bread from standard flour; *B*, bread from flour with 11 per cent gluten added; *C*, bread from flour with 25 per cent gluten added.

BREAD MADE FROM FLOURS WITH NORMAL AND INCREASED STARCH AND GLUTEN CONTENT.

bread from both normal flour and starch flour the same total quantity of flour was used. It was observed that less water was required for making the dough with the starch flour than with normal flour. The details of the experiment are given in the following table:

TABLE 46.—*Effect of addition of wheat starch to flour in bread making.*

Bread made from—	Size of loaf.	Weight of loaf.	Capacity of flour to absorb water.
	Inches.	*Ounces.*	
Wheat flour (14 ounces)	22½ by 17½	18.75	62
Wheat flour + 10 per cent wheat starch (13.6 oz. flour + 1.4 oz. starch)	23½ by 17	18.25	59
Wheat flour + 20 per cent wheat starch (12.2 oz. flour + 2.8 oz. starch)	21½ by 17	18.00	57

The expansion of dough by yeast fermentation depends upon the presence of gluten in the flour. The addition of 10 per cent of wheat starch did not decrease the size of the loaf, although it of course diminished the proportion of gluten in the flour. In one experiment the loaf from the 10 per cent starch flour was slightly larger than from the normal flour, as will be seen by comparing the two loaves in the following illustrations (Pl. III, A and B). Even when 20 per cent of starch was added the size of the loaf was not appreciably decreased (Pl. III, A and C). However, the quality of the bread was altered. The starch flour produced an inferior loaf which weighed less and which readily became dry and hard.

In a former report[1] it was also shown that the addition of 10 or 20 per cent of corn flour to wheat flour had but little effect in decreasing the size of the loaf. The explanation in all these cases is that while the addition of the wheat starch or the corn flour reduced the percentage of gluten in the flour mixture it did not alter the character of the gluten, the two gluten proteids, gliadin and glutenin, being in the same ratio to each other in the mixture as in the normal flour. The power of the dough to expand appears to be due more to the character of the gluten—that is, to the ratio of gliadin to glutenin—than to the percentage amount of gluten present. As long as the character of the gluten remains unchanged the tests reported show that wheat starch may be added to the extent of 20 per cent without materially diminishing the expansion of the dough, and consequently decreasing the size of the loaf.

While the size of the loaf was little affected by the addition of the wheat starch, the bread from the starch flours was shown by analyses to be less moist than that from the normal flour. It has been already mentioned that less water was required to make dough from the starch flours. In one of the experiments bread from normal flour, when

[1] U. S. Dept. Agr., Office of Experiment Stations Bul. 67, p. 22.

twenty-four hours old, contained 38.5 per cent water, that from flour containing 10 per cent starch 34.2 water, and from the flour containing 20 per cent starch 33.1 per cent water. What has been noted here in regard to the smaller amount of water required for making dough of the starch flour, and the drier bread produced, has also been observed in a comparison of two normal flours, one of which had a high and the other a low percentage of gluten of the same character.

In two experiments a comparison was made between bread from normal flour and bread from flour in which the proportion of starch was diminished. This was accomplished by increasing the amount of gluten present in the following way: A weighed quantity of flour was made into dough, and some of the starch was removed by washing in the usual way. The starch was collected, dried, and weighed. From the amount of starch removed and the composition of the original flour the decrease in starch content (or, vice versa, the increase in gluten content) of the altered flour was calculated. Bread was made from a mixture of flour from which part of the starch was removed and a weighed amount of normal flour, the total amount of the mixture used being the same as in the case of the bread made from normal flour. From the amount and composition of the flour from which the starch was removed and that of the normal flour the decrease in starch (or the increase in gluten) was calculated. In one case it was approximately 11 per cent and in the other 25 per cent.

TABLE 47.—*Effect of increasing the proportion of wheat gluten in bread making.*

Bread made from—	Size of loaf.	Weight of loaf.	Capacity of flour to absorb water.
	Inches.	*Ounces.*	
Normal wheat flour (210 grams flour)	12¾ by 9	12.00	62
Wheat flour + 11 per cent gluten added (187 gm. flour + 23 gm. gluten)	12½ by 9	12.75	64
Wheat flour + 25 per cent gluten added (158 gm. flour + 52 gm. gluten)	12 by 8¾	13.00	67

The bread made from the flour having a low starch content and a correspondingly high gluten content was, in appearance, in every respect like normal bread. The size of the loaf was not materially affected, as will be observed from the illustration. (Pl. III.)

The results of these experiments on the effect of increasing or diminishing the proportion of starch, and consequently decreasing or increasing the proportion of gluten in flour are in accord with those of experiments previously reported.[1] It is the gluten content rather than the starch content which determines the character of the bread. The character of the gluten apparently has more effect upon the quality of the bread than the proportion present in the flour, although the

[1] U. S. Dept. Agr., Office of Experiment Stations Bul. 67, p. 23.

latter factor affects somewhat the amount of moisture retained in the loaf. These experiments suggest that there is a limit beyond which it is inadvisable to increase the quantity of gluten in flour in order to produce a large-sized loaf of bread. An abnormally large amount of gluten does not yield proportionally a larger sized loaf.

WARM AND COLD FLOURS IN BREAD MAKING.

Experiments were made to determine the effect of cold and warm flours upon the bread-making process. The cold flour had been stored in a cold place, and had a temperature of 48° F. The warm flour was heated until its temperature was 98° F. These are not unusual temperatures for flours to reach when stored in cold or warm rooms at different seasons of the year. For comparison bread was also made from flour at 70° F., which was assumed to be a normal temperature. Only small amounts of bread were made in these tests, but the same quantities of material were used in each case. Possibly more striking results might have been obtained if larger amounts had been made. The following table contains the data of the experiments:

Table 48.—*Influence of warm and cold flours in bread making.*

Kind of bread.	Temperature of flour used.	Size of loaf.	Weight of loaf.
		Inches.	*Ounces.*
Bread made from cold flour	48° F. (9° C.)	20½ by 16¾	18.50
Bread made from warm flour	98° F. (37° C.)	22½ by 17	18.50
Bread made from flour of normal temperature	70° F. (21° C.)	23½ by 17	18.75

The yeast acted more slowly in the dough made from the cold flour than in that from flour of normal temperature. It required nearly half an hour longer for the former dough to reach the same degree of lightness as the latter. The dough made from the cold flour expanded more while in the oven than it did during the rising process. The dough made from the warm flour when placed in the oven had reached a higher degree of expansion than the cold-flour dough, and expanded but little more while in the oven. When taken from the oven there was little difference in the size of the loaves from the warm and cold flours.

It is believed by many persons that when fermentation takes place at a temperature much above the normal (70° F.) the bread produced has a slightly acid taste. In former experiments[1] on bread making it was observed that long fermentation produced bread with a higher degree of acidity than short fermentation, but the temperature at which the acid ferments are most active in dough apparently has not yet been determined. In the experiments reported above the amount of bread was too small to admit of accurate comparison as to acidity.

[1] U. S. Dept. Agr., Office of Experiment Stations Bul. 67, p. 21.

In these two experiments with warm and cold flours the most noticeable effect was the rate of expansion of the dough and the physical quality of the bread. The best bread was obtained when the flour had a temperature of 70° F.

INFLUENCE OF PROLONGED HEATING OF FLOUR UPON THE QUALITY OF BREAD.

Six experiments were made to determine the influence of prolonged heating of flour upon the quality of bread. In two of these the flour was heated for four hours at 100° C., in two for the same time at 70° C., and in two at 50° C. When heated at 100° C., the flour lost practically all of its moisture. It also underwent a slight chemical change, as was shown by the somewhat darker color of the sterilized flour. Doubtless the heat acted to some extent upon the three classes of nutrients of the flour, the albumen (proteid) being probably coagulated and the fats slightly oxidized, while the starch became slightly caramelized. A little dextrin may also have been formed. In addition to these chemical changes, heating probably destroyed the activity of the unorganized ferments of the flour, particularly the enzyms, as, according to Bourquelot,[1] the activity of the more common ferments, such as are found in the seeds of the cereal grains, is destroyed at temperatures ranging from 50° to 70° C. In the case of the flour heated at 50° C. there was a loss of moisture, but the chemical changes enumerated apparently did not take place, since the flour retained its normal color. As is well known, the activity of all ferment bodies is not destroyed at this temperature. At 70° C. the greater part of the moisture of the flour was expelled, but probably little chemical change took place except the coagulation of the albumen.

The results obtained in the test with the flour heated at different temperatures follow, the results obtained with normal flour being shown also for comparison.

TABLE 49.—*Influence of prolonged heating of flour upon the quality of bread.*

Kind of bread.	Temperature.	Size of loaf.	Weight of loaf.
		Inches.	*Ounces.*
Bread made from normal flour	Normal.	21½ by 16¾	18.75
Bread made from heated flour	50° C. (122° F.)	21½ by 16¾	18.75
Do	70° C. (158° F.)	20½ by 16⅞	18.50
Do	100° C. (212° F.)	19½ by 16	18.25

The bread made from the flour heated to 100° C. was darker in color and the loaf was smaller than that made from the same quantity of either the same flour which had not been heated or that heated at lower temperatures. From these tests it is evident that the chemical changes

[1] Les Ferments Solubles, p. 140.

which the flour undergoes when heated for some hours at 100° C. and the destruction of the soluble ferments alter the character of the flour and make it less suitable for bread-making purposes.

The bread made from the flour heated four hours at 70° C. was nearly normal, the loaf being only a little smaller and a little darker in color than that made from flour which had not been heated. As shown by a previous experiment, when bread was made of flour from which the water soluble proteids had been extracted, the loaf was normal in size and appearance.[1] Therefore it seems probable that the slight change which the albumen of the flour had undergone was not the cause of the changes noted in the loaf made from the flour heated for four hours at 70° C. It would appear that any modification of the bread-making qualities of the flour heated at 70° C. was due more to the destruction of the activity of the unorganized ferments than to any chemical changes which the flour had undergone.

Briefly stated, when flour was heated four hours at 100° C. the bread-making properties were impaired. When the same flour was heated for four hours at 50° C., no change in bread-making qualities was observed, while when heated for the same time at 70°, only a slight loss was noticeable. The change in bread-making properties in the latter case appeared to be due more to the destruction of the unorganized ferments of the flour than to chemical change of the proteids.

EFFECT OF BLENDING FLOURS UPON THE QUALITY OF BREAD.

As is well known, the gluten of flour is made up of two constituents—gliadin and glutenin. In a former report[1] it was shown that the removal of only part of the gliadin destroyed the bread-making properties of the flour. The gliadin plays an important part in bread making, and in flour of the highest bread-making properties there is a definite ratio of gliadin to glutenin, namely, 3 to 1. Many flours contain a large amount of gluten and total proteid matter and possess a high food value, but do not yield bread of the best quality. A study of such flours[2] has shown that this is due either to an excess or to a deficiency of gliadin. An excess of gliadin causes a soft, sticky dough, while a deficiency causes a dough which lacks normal expansion.

Experiments were undertaken to determine the effect of blending or mixing two flours of unlike character, one containing a large amount and the other a small amount of gliadin. Both flours were ground from spring Fife wheat and were as much alike as possible except in the character of the gluten.

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[1] U. S. Dept. Agr., Office of Experiment Stations Bul. 67, p. 23.

[2] Minnesota Station Bul. 63, "Proteids of wheat."

One sample (No. 150) was milled from hard Fife wheat grown in Winnipeg, and was an extreme type of what is commercially known as "hard wheat." The flour contained a high percentage of gluten and total proteids. Some of the gluten was separated by washing in the usual way, and was found to be deficient in elasticity. As shown by analysis, the gluten was composed of 58.3 per cent of gliadin and 41.7 per cent of glutenin. It was therefore relatively deficient in gliadin. The other flour (sample No. 151) was a very soft wheat, and, when analyzed, was found to contain gluten which yielded 70.1 per cent gliadin. This was a typical gluten of very soft wheat, being the direct opposite of that from sample (No. 150) in nearly every respect.

Equal parts by weight of the two flours (Nos. 150 and 151) were mixed, and comparative baking tests were made of the two flours and the mixture. Equal amounts of flour, yeast, shortening, etc., were used in all of the tests. The bread was weighed and measured as soon as it was taken from the oven. The composition of the flour, the quality and the gliadin-glutenin content of the gluten, the amount of dry baker's gluten, capacity to absorb water, and granulation of the flour are all given in the following table:

TABLE 50.—*Comparison of bread made from hard wheat flour, soft wheat flour, and a mixture of the two.*

Kind of flour used.	Water.	Protein (N × 5.7).	Total nitrogen as gliadin.	Total nitrogen as glutenin.	Fat.	Carbohydrates.	Ash.	Quality of gluten.	Dry baker's gluten.	Capacity to absorb water.	Granulation.
	Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*		*Per ct.*	*Per ct.*	
Hard wheat, No. 150	9.7	12.7	58.3	41.7	1.2	75.9	0.4	Hard	13.2	62	Medium.
Soft wheat, No. 151	10.1	11.4	70.1	29.9	......	......	.4	Soft	12.0	60	Fine.
Mixture of Nos. 150 and 151.	9.9	12.1	64.2	35.8	1.2	76.4	.4	Medium	12.5	62	

The hard wheat flour (No. 150) produced a loaf of good size, but not as large as might have been expected from its high gluten content. Many hard wheat flours, with 15 per cent less gluten, have been found to produce an equally large loaf. The soft wheat flour (No. 151) produced a soft, sticky dough, which expanded while rising, but collapsed during the baking process and produced a smaller loaf than the hard wheat flour. The size of the standard loaf from the hard wheat flour (No. 150) was 23½ by 18½ inches, and that from the soft wheat flour (No. 151) 21½ by 18½ inches, while the loaf from the mixture of the two flours (No. 152) was 23¾ by 18½ inches.

The hard wheat flour (No. 150) produced a loaf that weighed more than that of the soft wheat (No. 151). This was due to the fact that the former had a greater power to absorb water. The weight of a

standard loaf from hard wheat and soft wheat flours and the mixture of the two was 19 ounces, 18.5 ounces, and 18.75 ounces, respectively. The blended flour produced the largest loaf, while the hard flour produced the heaviest loaf. The soft wheat flour produced the smallest and lightest loaf. When the hard and soft wheat flours were mixed in equal parts by weight, the soft wheat flour did not reduce the size of the loaf, but the loaf was as large as that produced by either of the flours alone. When the hard and soft wheat flours were mixed the undesirable properties of the gluten of each were counterbalanced and a flour with a better bread-making quality was produced.

In the milling of flour the blending of opposite types of wheat is often resorted to in order to produce a better quality of flour. The blending of suitable wheat of different types before milling results in a flour with a gluten of different physical properties and a different gliadin-glutenin ratio from that from either sort of wheat alone.

These experiments indicate that a flour of a high food value, but of poor bread-making properties, may be improved by blending it with either a hard or soft wheat flour, as may be required, so as to produce a better balanced gluten for bread-making purposes, but the bread product is not equal in quality to that produced from wheat containing a normal well-balanced gluten.

SUMMARY OF RESULTS.

According to the chemical analysis of graham, entire-wheat, and standard patent flours milled from the same lot of hard Scotch Fife spring wheat, the graham flour contained the highest and the patent flour the lowest percentage of total protein. But according to the results of digestion experiments with these flours the proportions of digestible or available protein and available energy in the patent flour were larger than in either the entire-wheat or the graham flour. The lower digestibility of the protein of the latter is due to the fact that in both these flours a considerable portion of this constituent is contained in the coarser particles (bran), and so resists the action of the digestive juices and escapes digestion. Thus while there actually may be more protein in a given amount of graham or entire-wheat flour than in the same weight of patent flour from the same wheat, the body obtains less of the protein and energy from the coarse flour than it does from the fine, because, although the including of the bran and germ increases the percentage of protein, it decreases its digestibility. By digestibility is meant the difference between the amounts of the several nutrients consumed and the amount excreted in the feces.

The digestibility of first and second patent flours was not appreciably different from that of standard patent flour. The degree of digestibility of all of these flours is high, due largely to their mechanical condition—that is, to the fact that they are finely ground.

The results of three digestion experiments with large, three with medium, and three with small rations of bread and milk indicate that the quantity of the ration affected somewhat its digestibility. The small ration was more digestible than the large ration, but the differences were slight, and varied with the individual and with either the labor at which he was employed or with some other conditions at present undetermined. In the medium ration part of the nutrients were more digestible and part were less digestible than in the large ration.

In two digestion experiments with large and two with small rations of oatmeal and milk the increase in the digestibility of the small ration was greater than in the experiments with bread and milk.

The digestibility of the bread in the large and the small rations of bread and milk was greater than that of oatmeal in large and small rations. It is to be noted that the flour from which the bread was made was in a much finer state of division than was the oatmeal. These results are in accord with those observed in the comparison of graham, entire-wheat, and patent flours. Apparently the fineness of division of the particles in these foods had an influence upon their digestibility.

An increase in the proportion of starch in flour apparently caused a slight decrease in the digestibility of the protein. In three digestion experiments with bread made from flour in which the proportion of wheat starch had been increased 20 per cent the protein was found to be slightly less digestible than that in bread from normal flour.

The results of all the digestion experiments with bread from different grades of flour, with large, medium, and small rations of bread and of oatmeal, and with bread of high starch content, indicate that digestion coefficients are not constant, but vary to a limited extent with the individual peculiarities of the subject and the work at which he is employed, with the character and amount of food consumed, and with the proportions in which the nutrients are combined in them, as well as with some other conditions as yet not understood.

When wheat starch was added to flour with a high percentage of gluten containing 37.2 per cent glutenin and 62.8 per cent gliadin the size of the loaf was not reduced, even though the amount of starch added equaled 20 per cent of the weight of normal flour; that is to say, a given amount of the mixture of flour and wheat starch made as large a loaf as the same weight of normal flour. But the physical qualities of the bread were materially altered by the addition of the starch. As would be expected, analysis showed that there was less moisture in the flour diluted with starch, and the bread made from it was not so moist as that made from normal flour. When the proportion of starch in flour was diminished by the addition of moist gluten to normal flour the size of the loaf was not increased. The experi-

ments upon the effect of increasing and diminishing the proportion of wheat starch in flour showed that it was the gluten content rather than the starch content of flour which affected its bread-making qualities, and that, within the limits tested in these experiments, the size of the loaf is determined by the properties or character of the gluten, especially the ratio of gliadin to glutenin, rather than by the percentage amount of gluten in the flour.

The effect of the temperature of the flour used for bread making was most noticeable in the rate of expansion of the dough and the physical quality of the bread. The best bread was obtained when the temperature of the flour was about 70° F.

The prolonged heating of flour affected its bread-making qualities. Flour heated four hours at 50° C. (122° F.) produced a normal bread; flour heated four hours at 70° C. (158° F.) produced a nearly normal loaf, since it had lost but little of its color, lightness, and power of expansion, while flour heated four hours at 100° C. (212° F.) produced a smaller loaf and one of darker color than that from normal flour.

By blending hard and soft wheat flours the undesirable properties of the gluten of each were counterbalanced. When flour containing a high percentage of glutenin was mixed in equal proportions with flour containing a high percentage of gliadin the loaf produced was larger and of better quality than that from either of the flours alone. The bread from the blended flour, however, was not equal in quality to that produced from wheat containing a normal, well-balanced gluten.

Briefly stated, the more important deductions from the results of these investigations are that the bread-making qualities of patent flour milled from a high grade of wheat were not improved by the increase of the proportion of either starch or gluten, and that the nutritive value of the flour in so far as the quantities of digestible or available protein, fats, carbohydrates, and energy are concerned, was not increased by milling the wheat so as to retain a large proportion of the bran and germ as in the entire-wheat and graham flours. The digestibility of the several mineral constituents as calcium and potassium phosphates in the different flours was not studied.

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